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NEGATIVE RAKE MILLING

by

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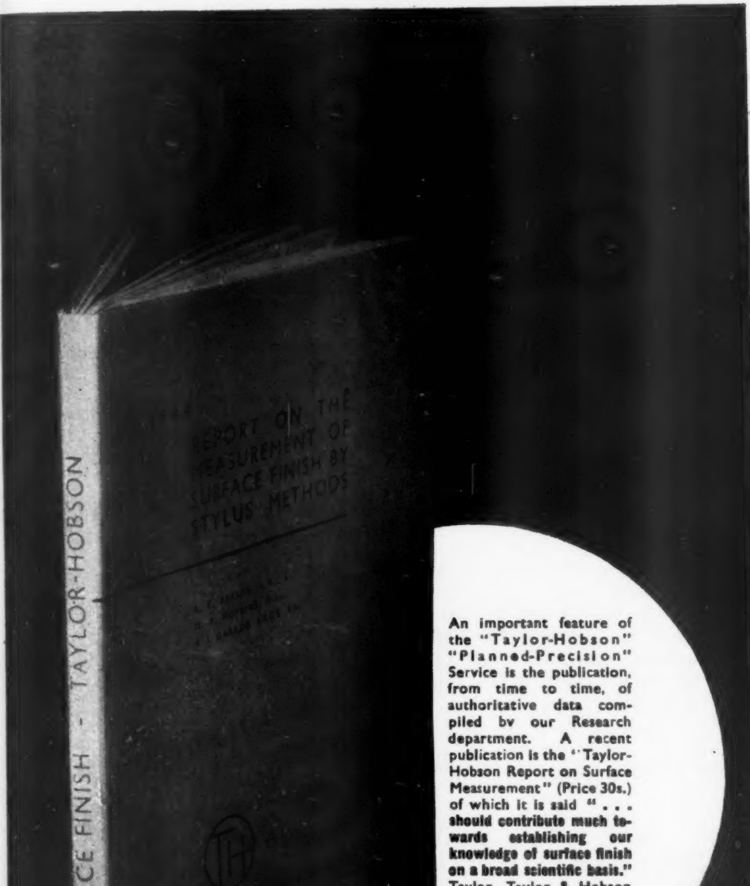

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NEGATIVE RAKE MILLING *

By H. ECKERSLEY, M.I.P.E., A.M.I.Mech.E.
(A. C. Wickman, Ltd.)

Paper presented to The Institution of Production Engineers, Manchester, 25th October, 1944; Crewe, 24th November, 1944; Liverpool, 2nd December, 1944; Blackburn, 13th January, 1945; and London, 13th April, 1945.

During the past two years a new technique in milling has been developed, both in this country and in the United States, employing cemented carbide milling cutters, using negative rakes. There is a general impression that the application of negative rakes is new, and therefore, questionable in its results, and I feel it essential to remove this illusion at the outset.

The first applications of negative rake tools were made many years ago to those turning tools which were being used on interrupted cuts. In Yorkshire many applications of negative rake turning tools are common practice on heavy forgings, steel castings and similar work, which by its very nature introduces problems similar to those encountered when milling. If it is realised that a milling cutter is merely equivalent to a multiple turning tool, then the similarity will be understood, in so far as all milling cutter blades are continually under interrupted cutting conditions.

In using the turning tools discussed, negative rakes up to about 15° have been in common use and grades of carbides have been evolved during the past ten years which satisfactorily meet the conditions of shock imposed by heavy interrupted cuts. Advantage has been taken of this experience in the evolution of the milling cutter with negative rakes and the selection of these rakes will be discussed later in this paper.

Design of Cutters.

The following factors had to be borne in mind when considering the design of cutters to be used in milling relatively high tensile materials :—

1. A very large number of modern milling machines have been installed in this country since 1938 and are already equipped with a feed and speed range suitable for milling high tensile steels. This statement has reference only to first-class machines.
2. The usual design of a milling machine spindle caters for radial load on the front bearings and a much lighter thrust load,

* *This paper was awarded the Institution Medal for the best paper presented by a Member during the Session 1944/45.*

both often being taken care of by the use of dual purpose bearings. The significance of this statement is that such spindle design imposes a limitation on the degree of negative rake which can be employed without undue damage to the machine and consequent shortening of its life. (Experiments carried out in the United States during 1941/2 employed extreme rakes up to 30° negative, but it was realised that this was excessive for the reasons given.) Drawing on the experience of interrupted cutting in turning, it was decided to commence experiments with 10° of negative rake. This was later reduced to 5° as a compromise based on experience and for the sake of standardisation in production of cutters.

3. The establishment of data could only be carried out by trial and error methods in the early experiments and although tests would no doubt produce reliable data, it was felt that tests under production conditions would ultimately be more valuable and the co-operation of one or two factories was therefore sought and obtained. The results of these tests will be seen later.

4. As control of tests is simpler in face milling applications, it was decided to adopt such work as would give continuity in similarity of component for reliability and consistency of test results.

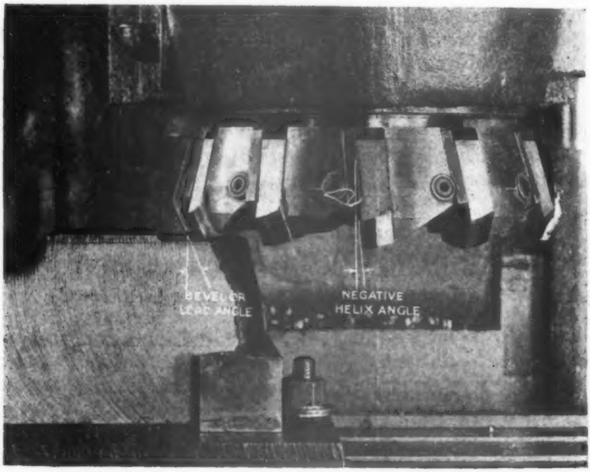


Fig. 1.

5. Considerations of first cost and maintenance led to the adoption of an inserted blade type of cutter for ease in modifications of rakes and helix angles, as well as cheapness in blade replacement during use on production.

Fig. 1 shows a cutter assembled on the spindle of a Milwaukee 3K vertical milling machine. The bevel angle on the blade is designed to spread the chip load for reduction of unit pressure to a minimum figure. It will be noted that the body of the cutter supports the blade immediately behind the cutting edge, and yet provides adequate space for the clearance of chips. The body itself is heavy, to obtain to some extent flywheel effect.

With the set-up as shown, a depth of cut of ·72″ has been taken on a 65-ton tensile steel component at 3½″ per minute without any disturbance of the blade.

Helix Angle.

The top diagram "A" in Fig 2 indicates the strike of the blade

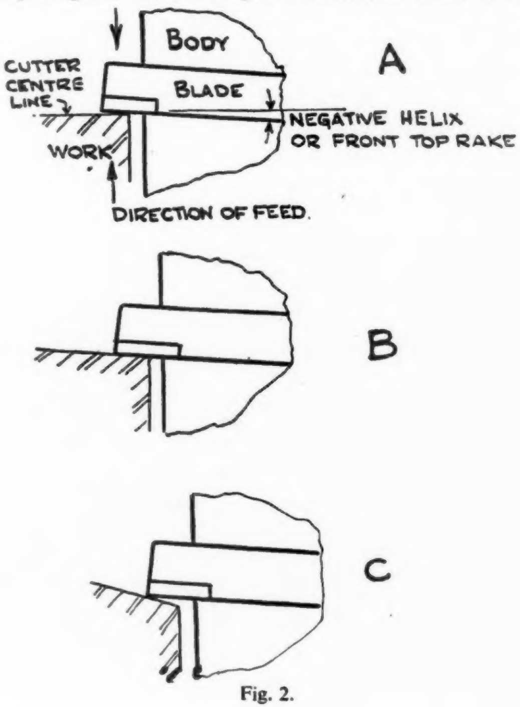


Fig. 2.

on a workpiece using a negative helix or front top rake. It will be observed that the first strike is part way up the tip. The diagram at " B " shows the effect of a strike when the surface of the material being cut is parallel with the front top rake of the blade, that is, the full contact is made between the tip and the work, resulting in very heavy load at the moment of impact. At " C " the extreme edge of the tip strikes the work first. This condition results in the carbide flaking on the front of the tip. The negative helix or shear as indicated in diagram "A" should always be sufficient to cause the first strike to take place as indicated in the top diagram. This is the major consideration affecting the selection of helix angle in a milling cutter, or front top rake in the case of a turning tool.

RECOMMENDED SIDE TOP RAKE.

Material	Tensile Tons per sq. in.	Side Top Rake
Forging	30/40	0°
Casting	30	5° neg.
Forging	40/60	5° neg.
Casting	40	10° neg.
Forging	60/100	10° neg.

Fig. 3.

Side Top Rake.

The principle of negative rake milling is entirely dependent upon the side top rake used in conjunction with a negative helix or front top rake. As explained in the previous paragraph, the function of the negative helix angle is to provide a counter to shock on the cemented carbide tool, whilst the function of a negative side top rake is to induce such pressure producing a chip that the chip is plasticised at the moment of partition.

The combination of negative helix angle and negative side top rake is obviously capable of considerable variation affecting the direction of cutting pressure and consequently the direction of chip flow. The natural direction of chip flow in the case of a face milling cutter is across the face of the blade, that is, following the direction of side top rake. In the case of a slotting cutter, radially towards the centre of the cutter or along the front top rake. It is, therefore, the side top rake or radial rake which requires to vary for production of different cutting pressures.

Steel of low machinability requires greater negative side top rake than mild steel to induce plasticising of the chip. In the absence of close research into this subject, estimation based on practice supports the adoption of side top rakes recommended in Fig. 3. These figures, based on tne adoption of a negative helix angle of 10° which meets most requirements, are to some extent, a compromise for simplification of manufacture and maintenance. It must be recognised, however, that an increase in the angle of negative helix will demand a decrease in the angle of negative side top rake for maintenance of equivalent cutting pressure. The degree of effective combined rakes must, therefore, be fixed at a minimum figure just sufficient to produce a plasticised chip. Excessive effective rake will result in cratering of the carbide due to the unnecessarily high cutting pressure preventing free chip flow.

Feeds.

The early applications were made with feeds of 0·001″ per tooth, but experience has shown that much higher tooth loading is economical. Feed per tooth now reaches 0·020″ on steel components produced by machines designed for cemented carbide cutters. Recently-modern machines produce economically using roughing feeds from 0·004″ to 0·007″ per tooth, due to limitation in power input and table feed rates. American built milling machines of the Milwaukee and Cincinnati class usually provide table feed rates up to about 40″ per minute and over with motors of 10 to 15 h.p., whilst British built machines generally have restricted table

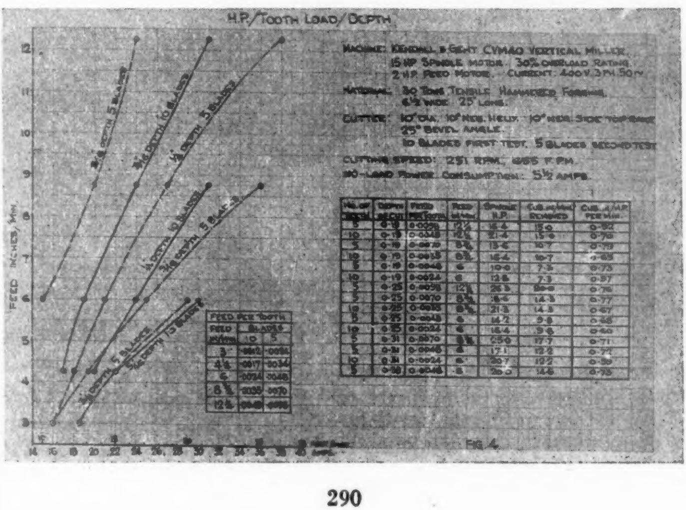
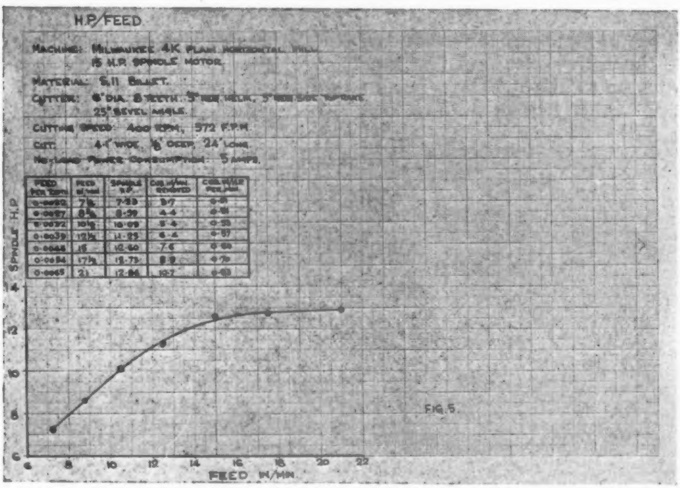


FIG. 4

feed rates and lower power input. It is thus possible to exploit cemented carbide cutters to better advantage on American machines than on British machines.

Fig. 4 indicates the results of a series of tests on a Kendall & Gent CVM.40 vertical miller, which is representative of the best British milling machines. It will be apparent that an increase in the feed per tooth by reducing the number of blades operating at any feed in inches per minute covered by the tests, gives an increase in the rate of metal removal relative to the horse-power consumed. These tests were carried out with a combination of increase of feed and depth of cut. The maximum feeds used were still within the capacity of the machine to take such loading, and the high rate of metal removal is interesting as compared with the probable metal removal rate with high speed steel cutters on the same type of work. It will also be apparent that the rate of increase in feed is more rapid than the relative increase in horse-power consumed.

Fig. 5 relates horse-power to feed with a constant depth of cut throughout tests taken on a Milwaukee 4K plain horizontal milling machine. This machine is capable of very much higher feed rates than the Kendall & Gent CVM.40, although the spindle motor horse-



power is the same, but these tests confirm the reduction in horse-power consumed as the feed rate per tooth is increased. The object of this test was to find the smallest economical tooth load, shown to be about 0·0045″. The minimum feed rate is that where the chip is

red as it leaves the work. A feed too fine will allow heat dissipation throughout the workpiece instead of through the chip. Alternatively, a machine overloaded by the fitment of a motor which causes over-power in the machine will also lead to heated workpieces.

Whilst it is indicated that to a very large degree the metal removal capacity of the machine influences the feeds selected, trial and error methods must be used to select the most suitable feed and an examination of the chip produced should show that the chip is annealed, excepting, of course, in the case of air hardening material. It is rare that similar results are obtained on the same job with similar feeds and speeds from two machines of dissimilar design and make. It is hoped, however, that as a result of the data now being introduced to machine tool makers, new designs of machines will be made available to exploit cemented carbide cutters economically. In the meantime, considerable use of existing machines can be obtained with limited results in rate of feed.

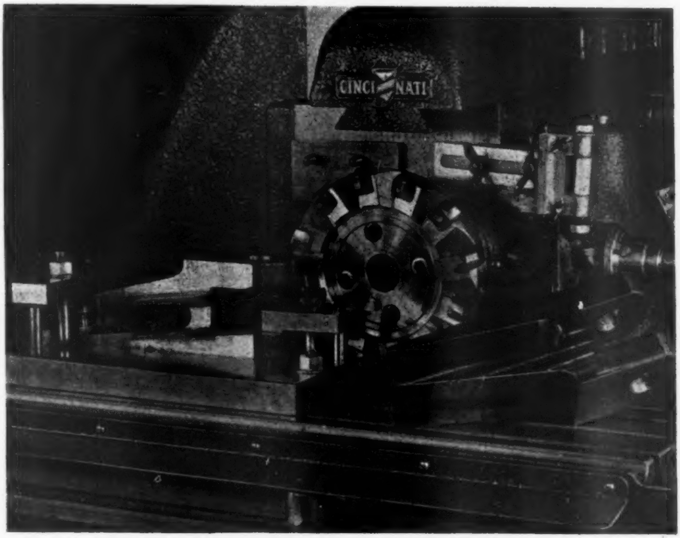


Fig. 6.

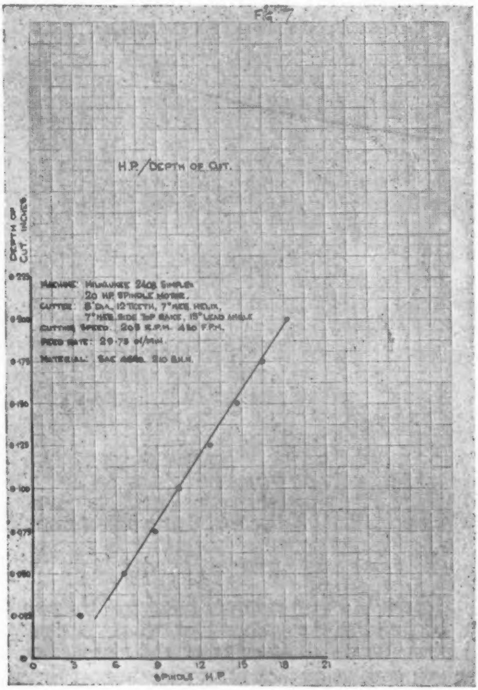
The set up shown in Fig. 6 is interesting from the point of view of the method of holding the component which is clamped on the bottom flange at the point of entry of the cutter, but on the top flange at the exit end, using jack screws to support the flimsy struc-

ture of the component. The finish milled component on the machine table indicates the high finish obtained.

In this application down-cut or climb milling is employed. The component is approximately 12½" long and is machined at 790 ft. per minute at a feed rate of 3½" per minute, using a 10" diameter cutter with 10 teeth. The material is S.11 and the feed is limited by the available horse-power. A reduction in the number of teeth in the cutter would considerably improve the efficiency of cutting and allow a higher table feed rate to be obtained for similar power consumption.

Depth of Cut.

The Kearney & Trecker Corporation of Milwaukee, U.S.A., have carried out tests to determine the relationship between variations of depth of cut and horse-power comsumption. Fig. 7 graphs the results of these tests carried out on a Milwaukee Simplex 2408 horizontal



miller with a 20 h.p. spindle motor. A straight-line relationship is shown, and since the ratio between depth of cut and horse-power is greater than 1, the increase in horse-power is proportionately less than the increase in the depth of cut. For example, increasing the depth of cut from 0·050″ to 0·100″ increases the horse-power from 6 to about 10½.

Cutter Life.

The desirability of revision of milling machine design has already been mentioned and the results of cutter life tests carried out by The Kearney & Tucker Corporation, as indicated in Fig. 8, qualify this claim. The two machines used in these tests were both specially designed for high metal removal using negative rake cemented carbide cutters, and as will be seen from the figures, high feed rates are obtained with a chip load per tooth which is considered reasonable on a suitable machine. The figures given of cubic inches of metal removed per horse-power per minute are higher on the average than the figure of 0·6 cub. in. of mild steel per horse-power per minute normally taken by machine designers as a basis for metal removal capacity calculations.

Life of cutters in these examples is low by British standards, life being measured by the volume of metal removal between grinds. This short life can be due to either inferior cemented carbide or excessive negative side top rake causing cratering. The material cut during these tests is approximately 50-tons tensile.

The results tabulated in Fig. 9 indicate inefficiency in some degree in each of the cases quoted. In the first example on this chart a standard Cincinnati No. 3 vertical milling machine is used for production of a very light job. The limiting factor in this case is the speed at which the operator can re-load a jig, which indicates the necessity for a change in the method of holding the work, at the present time carried in a multiple fixture on a circular table. The results must be considered good, however, the life of the cutter in terms of components produced being very high indeed, but the removal rate is low. There will be many jobs of this nature, however, where a standard machine of existing design will function very satisfactorily, but with the tooth load of only ·0012 as in this case, the cutter life is bound to suffer. By comparison with the life of a high speed steel cutter, however, the results justify the application. Reduction of cutting speed to about 700 f.p.m. would improve cutter life.

In the second case the depth of cut is excessive, due to faulty forgings produced from over-size dies. The machine is, however, over-powered and considerably overloaded, although the feed rate per tooth is very low. The volume of metal removed per horse-power per minute is fairly good, but the results of this overloading

CUTTER LIFE TESTS—KEARNEY & TRECKER CORPORATION.

Cutter		Size of Workpiece			Operating Conditions					Results				
Dia. in.	No. of teeth	Length in.	Depth in.	Width in.	Speed R.P.M.	Speed S.F.M.	Feed in./min.	Chip load/tooth	Machine type	No. of passes	Spindle h.p. consumed	Cu. in per pass	Total cu. in. removed	Cu. in./ h.p./min.
8	12	12·5	0·150	3·56	205	429	29·25	0·012	Simplex 2408	54	15·2	5·93	321·0	1·04
8	12	12·25	0·150	3·00	222	465	30·00	0·0112	50 CSM Horiz.	50	20·5	5·54	277·0	0·659
8	12	12·38	0·150	3·00	205	429	36·75	0·0149	Simplex 2408	17	16·75	5·74	97·5	0·987
8	12	12·38	0·150	3·00	205	429	36·75	0·0149	Simplex 2408	27	16·75	5·74	155·0	0·987
8	10	32·75	0·150	5·50	205	429	36·75	0·0179	Simplex 2408	13	28·7	27·0	351·0	1·06
8	10	32·75	0·225	3·63	205	429	36·75	0·0179	Simplex 2408	8	28·14	26·7	214·0	1·09
8	10	52·0	0·150	5·5	205	429	29·25	0·0142	Simplex 2408	12	28·14	42·9	514·8	0·86
8	10	52·0	0·150	3·5	250	512	29·25	0·0119	Simplex 2408	12	19·05	27·3	328·0	0·82
8	10	54·5	0·150	5·5	380	796	29·25	0·0077	Simplex 2408	9	28·14	45·0	405·0	0·63
8	10	54·5	0·150	3·563	250	512	36·75	0·0147	Simplex 2408	12	21·4	29·1	349·1	0·92
8	10	52·0	0·150	5·5	205	429	29·25	0·0142	Simplex 2408	13	28·94	42·9	558·0	0·85

In each case cutters with 7° neg. helix, 7° neg. side top rake and 15° lead were used ; inserted blades. Material in all cases 210 B.H.N. SAE.4640 forgings.

Fig. 8.

CUTTER LIFE TESTS.

EXAMPLES FROM BRITISH PRACTICE.

CUTTER					WORKPIECE			MATERIAL		OPERATING CONDITIONS					RESULTS					COMPONENT
Dia. in.	No. of teeth	Rake deg. Neg.	Helix deg. Neg.	Lead deg.	Length in.	Depth cut.	Width in.	Spec.	Tons sq. inch	Speed R.P.M.	Speed S.F.M.	Feed in./min.	Chip load/tooth	Machine type.	No. of passes	Spindle h.p. consumed	Cub. in per pass.	Total cu. in. removed	Cu. in./ h.p./min.	
8	10	5	5	25	2½	·18	2½	Forg.	60	450	952	5¾	·0012	Cincinnati No. 3 vert.	1400	6	1·125	1575	0·43	Con. rod cap.
10	12	5	5	25	12½	·72	3¾	Forg.	65	320	837	3½	·0009	Sundstrand Hor. Hydr.	42	12½	22·5	945	0·75	Root end fitting.
10	10	10	10	25	12⅛	·44	3¾	Forg.	65	302	790	3½	·0016	Milwaukee No. 3K vert.	75	10	13·5	1012	0·58	Root end fitting.
8	10	5	5	25	6½	·25	3½	Forg.	45	545	1024	10½	·0019	Milwaukee No. 3K vert.	300	10	3·5	1050	0·92	Engine mtg. block.
6	8	5	5	25	10	·08	3¾	Forg.	70	178	270	3⅝	·0025	Cincinnati No. 2 vert.	130	5	2·96	384	0·21	Root end fitting.

All machines used were standard machines, and performance recorded under production conditions. Repeated continuously on production batches.

Fig. 9.

are seen in the number of passes which are made between re-laps of the cutter as compared with the third application on this table, which deals with exactly the same job produced from new dies. The depth of cut in this case is only ·44, but the machine being more capable of taking this cut, 75 components are obtained per regrind of the cutter, and the total volume of metal removed between re-laps is higher.

The next example loads the machine normally, but very much higher feed rates would be possible if more horse-power were available, and cutter life would be improved by a reduction in cutting speed.

In the last example, although the machine is a light one and is low-powered, the volume of metal removed per h.p. per minute is very low, and a much higher feed rate should be used. It is probable that the rate of feed could be trebled on this job, with a probable increase in the number of components produced per re-lap of the cutter. The cutting speed should be increased to about 500 ft. per minute.

In each of the cases quoted the number of teeth in the cutter used should be reduced to about half in view of the power limitation of each machine used. All the examples in this table have been chosen deliberately to illustrate typical inefficiencies, and are not representative of the majority of good applications throughout the country.

Bevel Angle.

It has been proved by experience that a bevel angle of 15° gives the highest number of workpieces per regrind. Variations of bevel angle above or below 15° reduces the life of the cutter. Steeper angles result in an increase in unit pressure along the cutting edge, causing a more rapid break-down of the cutting edge, whereas flatter angles give a break-down in the cutting edge due to the large width of contact.

Where a bevel angle can be applied, as in straight-forward face milling, it is essential to use it to ensure a low unit pressure on the carbide tips, but where milling up to a square shoulder is necessary, some sacrifice of cutter life must be expected.

Cutter Diameter.

The best ratio of cutter diameter related to width of work in face milling is that where the cutter diameter is 50% greater than the width of face to be cut, assuming that the centre line of the cutter coincides with the centre line of the workpiece face. If a cutter is used which gives a larger ratio than 6 : 4, the cutter should be offset slightly so that the angle of entry of the cutter blade is similar to that which would be obtained if a cutter of the correct proportion were used.

Similarly, a cutter with a smaller ratio should be offset to give an equivalent angle of entry. An excessive angle of entry reduces cutter life, due to the increase in impact load and reduction in shearing action. A small angle of entry used in conjunction with a small diameter cutter results in shortened life. The small radius of the arc of contact also contributes to shortened life.

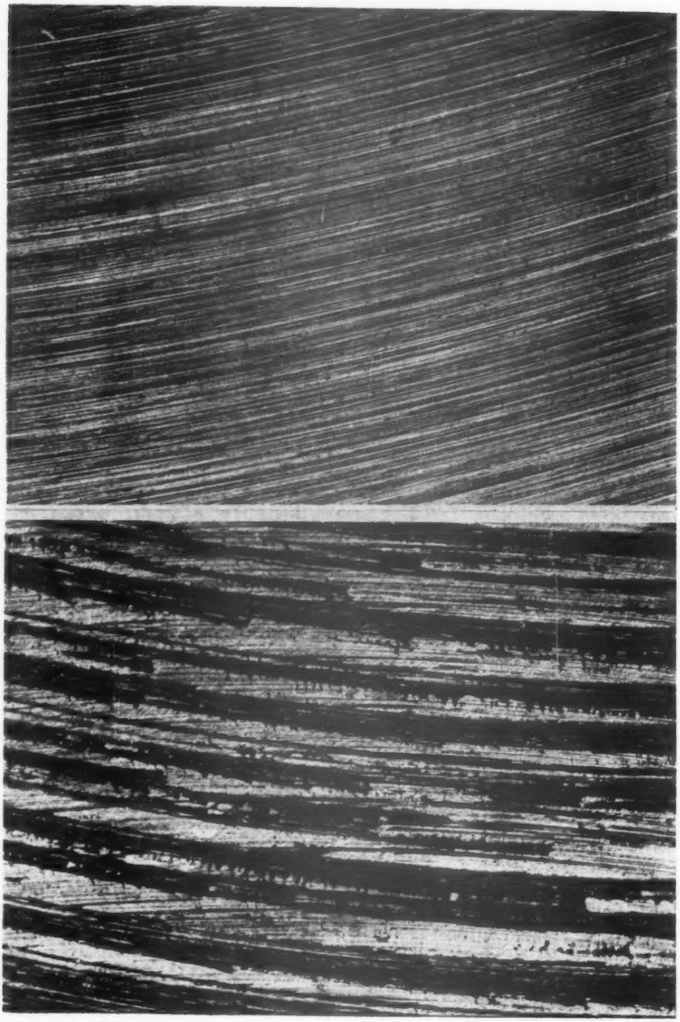
Where conditions limit the diameter of cutter which can be employed, the peripheral speed should be increased for quicker evacuation of chips, and at the same time the chip load per tooth should be slightly reduced so that the feed rate in inches per minute is the same. A coarser pitch of blades can also assist economical performance under these conditions, using the same tooth load as before, but with a proportionate reduction in the total feed rate, arising out of the reduction in the number of teeth in the cutter.

Fig. 10 illustrates the comparative finishes obtained with high speed steel and cemented carbide cutters on S.11 material with a magnification of 8 : 1. In the case of the high speed steel application where normal shop practice is followed, the surface is torn in parting the chip from the parent metal, but there is no sign of tearing of the surface milled with cemented carbide.

Condition of Machines.

Close observation of machine condition prior to application of cemented carbide cutters has exposed the fact of inadequate appreciation of machine condition relative to metal removal performance. For example, as the majority of modern milling machines are driven by vee belts, it has been the practice of engineers supervising the first application of cemented carbide cutters, to check the motor drive before commencing cuts. It is consequently recommended that the following points be carefully observed before a carbide cutter is applied, to avoid the subsequent breakage which is bound to occur unless these points are attended to :—

1. Make sure that the vee belts are all driving, that there is no shortage of belts and that the belt surfaces are in good condition, so that the maximum h.p. from the motor is transmitted.
2. Make certain that main driving clutches are correctly adjusted.
3. Electrical overloads should be correctly set.
4. Spindle oil seals should be leaf-proof, as a spot of oil will find its way along the spindle and eventually on to the cutter, causing a crack in the tip, leading to subsequent breakage of more than one blade.
5. In assessing the feed which can be applied to any component, the maximum depth at any point of the traverse must be taken as the controlling factor in settling the rate of feed according to the available h.p., as this will cause a peak load which must



Cemented carbide cutter finish on S.11.

Fig. 10.

H.S.S. cutter finish on S.11.

be taken into account. It is not sufficient to take the average depth of cut for calculation of the cross section of metal removed.

6. As a basis of calculation of horse-power requirements, a tentative figure of 0·75 cu./in. of metal removal per minute per h.p. should be taken for steels of 40–65-tons tensile. Variations from this figure, usually upwards, can be made after experience of cutter performance and horse-power consumption.
7. The first application on any machine should not be taken unless an ammeter or watt-meter is wired into the circuit for some guidance on motor loading.

Influence on Machine Design.

The considerable experience gained during the past four years in the application of cemented carbide cutters to materials ranging between aluminium alloys and the higher tensile steels indicates the

RECOMMENDATIONS FOR MACHINE DESIGN.

	Machine for non-ferrous materials	Machine of ferrous materials
Feed range ; inches per min. ...	18–240	4–80
Speed range ; r.p.m.	500–3000	50–1250
Rapid traverse ; inches/min. ...	150	150
Main drive motor	Up to 50 h.p.	Up to 50 h.p.
Feed and rapid traverse motor ...	5 h.p.	5 h.p.
Max. dia. of cutter ; inches ...	20	20
Coolant system	Generous	None

Fig. 11.

necessity for two distinct types of milling machine, and whilst the machining of aluminium alloys has not been discussed in this paper, it is not out of place to draw comparisons for the guidance of machine tool designers. Comparative specifications are, therefore, outlined in Fig. 11 for consideration of this point, bearing in mind that whilst in the past a milling machine of any one type has been used for all kinds of materials, in the future this will cease to be economical.

The comparisons made are based on two machines of equivalent

table capacity about 18″ × 72″ as an example. In each case it is recommended that a flywheel be mounted on the cutter spindle immediately adjacent to the final drive gear. The final drive to the spindle should be through a large diameter helical gear with ground teeth. A bed type table support should supersede the knee type machine, and the table should be driven through a hydraulic screw. A pneumatic swarf evacuator should be built into the machine with a nozzle adjacent to the cutter to evacuate swarf as produced. This system is in common use in this country on high production milling machines cutting spar booms for aircraft. A coolant system is required only in the case of machines for light alloys. It must be omitted, of course, on the machine designed for iron and steel.

The limit of cutting speeds for aluminium alloys has not yet been found, but success has already been achieved in maintaining economic cutting speeds up to 15,000 surface feet per minute. The 80″ per minute feed rate recommended as a tentative maximum for the machines designed for iron and steel will probably be superseded by higher feed rates within a few years, 80″ being easily possible on cast iron with a machine similar to that specified.

Where machines of large table capacity are being considered, it is essential not to overlook the advantages of the travelling head type machine in preference to the travelling table type for economy in floor space occupied.

Conclusion.

It is true to say that the technique of milling, even with high speed steel cutters, is one of the least understood amongst production processes. Choice of cutters from the point of view of diameter, location of work, hand of spiral and number of teeth, diameter of arbors and the size of machine are invariably subjects around which many mistakes are made.

The choice of machine is often made on the basis of table capacity rather than metal removal capacity. It is recommended that cemented carbide cutters be applied to machines with driving motors of not less than 10 h.p. A machine of the capacity of a Milwaukee No. 3K or Cincinnati No. 3 will absorb 5 amps. when running light, and this figure represents the greater proportion of the power input for the majority of work going through the normal machine shop, as high speed steel cutters rarely exploit the machine to its full capacity.

The maintenance of cutters is an important factor to bear in mind. Unfortunately, there are few tool and cutter grinding machines capable of reproducing accuracy in the running of the cutter blades, and more care in grinding is necessary than in the case of high speed steel cutters. It is important, when cutter grinding, to avoid the production of large radii wherever possible. Rather should the

design of the blade be such that a flat chip is produced, as a deformed chip produced by a radius cutter raises the horse-power consumed.

There is still considerable experimental work required for the establishment of optimum rakes and cutting speeds for various materials and cutting conditions, but the facilities for cutter grinding to some extent control these rakes until better machines are available for the purpose.

It has no doubt been noticed that slotting cuts have had little attention in this paper, and the reason is that, although a number of cutters are in work under production conditions, the performances are so dependent on the nature of the work itself that it is dangerous to generalise in this type of cutting. The practice in this country so far has been to use cutters with an effective negative helix of about 3°, and an effective negative side top rake of about 10°, with blades pitched coarsely in the body, whilst American practice as established by The Kearney & Trecker Corporation would indicate a no-degree helix angle and a 15° negative side top rake as presenting the most effective combination.

Without attempting to over-estimate the caution which must be applied in using cemented carbide cutters, it is recommended that factory executives make use of available expert knowledge before attempting to utilise cemented carbide cutters in their shops, at any rate in the first application, and to this end it is hoped that the information given in this paper will enable production engineers to extend the utilisation of their plant with better economic production in the machining of highly stressed parts.

APPENDIX.

Cutting Speeds.

As a result of questions repeatedly asked during discussion, the graph illustrated in Fig. 12 is submitted with recommended cutting speeds on steels, using negative rakes on cemented carbide tools, generally in accordance with the principles laid down in the paper. The graph is designed on the use of machines in good condition with adequate power input.

Flywheels.

Fig. 13 illustrates the application of a flywheel to a horizontal milling machine with small diameter driving gears to the spindle. The flywheel is mounted on the cutter spindle exactly as the cutter would fit, but carries on its front face driving keys and a spigot to take the cutter. The screws holding the cutter pass through the flywheel into the spindle nose.

In this application, the machine used was over five years old, and the use of a cutter without a flywheel caused breakage of the teeth after a very short time, but after the fitment of the flywheel, an

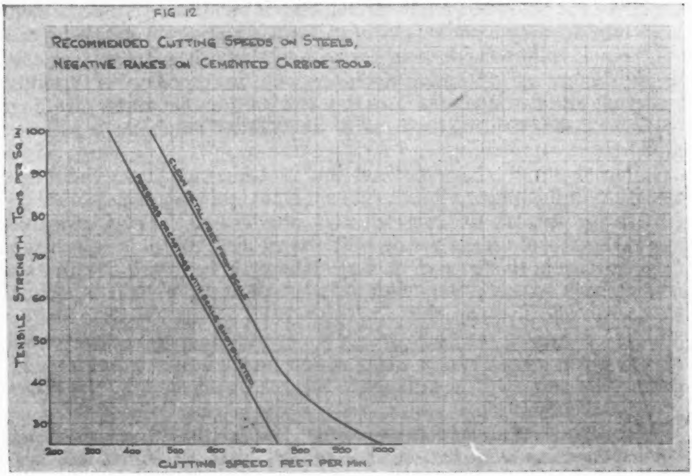


FIG 12
RECOMMENDED CUTTING SPEEDS ON STEELS,
NEGATIVE RAKES ON CEMENTED CARBIDE TOOLS.
TENSILE STRENGTH TONS PER SQ IN
100
90
80
70
60
50
40
30
CLEAN METAL FREE FROM SCALE
200
300
400
500
600
700
800
900
1000
CUTTING SPEED FEET PER MIN

Fig. 12.

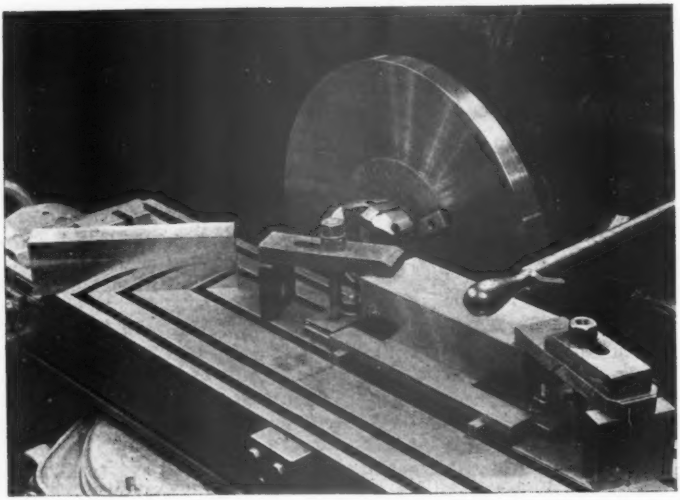


Fig. 13.

excellent job was produced and a sample block milled by this cutter is shown on the machine table. The photograph is untouched and the reflection of the table slots is an indication of the high finish obtained.

The machine spindle bearings were so worn that about 0·015" of end play could be measured with the spindle stationary. The fly-wheel eliminates the effect of this end play to a considerable degree.

Machine Design.

A bed type horizontal miller is illustrated in Fig. 14 and this machine follows generally the lines suggested in the later part of the paper under the heading: "Influence on Machine Design." In this case, adjustment vertically is obtained by movement of the head,

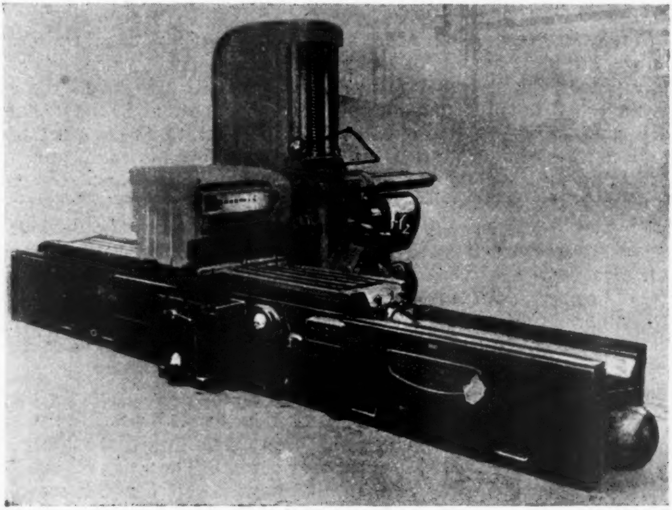


Fig. 14.

as in the case of the orthodox production milling machine, instead of adjustment of a knee carrying the table in the more common type of milling machine. A vertical miller of the same design would require to incorporate a head with vertical adjustment, or with a spindle quill with sufficient vertical adjustment to give adequate capacity under the cutter.

Climb Cutting.

The principle outlined in the author's reply to Mr. Bateman

during the Manchester discussion, applies equally to face milling applications, where conditions of cutting are similar, on a horizontal miller, in which case the adoption of climb cutting induces cutting pressures downwards towards the table.

Climb cutting methods are also, of course, applicable to a vertical miller, although the principle is perhaps not so apparent. In such an application the direction of cutting pressure should be towards the column of the machine.

DISCUSSION.

Manchester, 25th October, 1944.

MR. F. OSBORNE (*Section President*): Ladies and Gentlemen: The meeting is now open for discussion. Will any speaker please give his name clearly before asking any questions.

MR. SPARSHOTT: I have enjoyed every minute of Mr. Eckersley's lecture, but there are one or two points I would like clarified. Slides were put on the screen showing the comparative finish between a high speed steel cutter and a cemented carbide cutter. I take it that these cutters had negative rakes. I would like to know whether climb cutting or conventional cutting was employed in each case.

It is my opinion that a negative rake cutter will cause surface damage to the material being cut, with damage to a much greater depth than is normally produced with positive rakes. The damage caused to the surface probably upsets the crystals in the steel being cut. Hardening of the workpiece after milling will probably cause cracks or disruptions, unless the material is normalised immediately after milling. Can the Lecturer say whether research has been carried out to establish the amount of damage done to the workpiece by negative rakes.

MR. ECKERSLEY: The high speed steel cutter used to obtain the finish shown on the screen was a standard cutter with positive rakes working on an operation which had been current on that material for a matter of three years, using similar cutters. The finish obtained is the normal finish expected from that type of cutter, and is representative of the finish obtained in any other shop on similar material. This cutter operated on conventional milling. The cemented carbide finish is also the normal finish obtained on that particular material, and in this case climb cutting was used.

I do not agree that damage to the surface structure of the material is caused by the application of negative rakes, and I think that the comparison of finishes shown on the screen supports this claim. Damage to the material surface is more likely to occur from the plucking action of a positive rake indicated by the pitting of the surface, than with the smooth shear cut obtained from a cemented carbide cutter. I have no evidence with me which would prove this

point, excepting to say that laboratory tests have been carried out by a number of concerns in this country, which prove that no detrimental effects on the material are caused by negative rakes, or by the high speeds used with cemented carbide cutters.

I think the point is further proved when it is considered that many thousands of firms in this country have used cemented carbide tools for a considerable number of years for production of components requiring heat treatment and subsequent use of the component in critical conditions. A very large number of these applications are now carried out, using negative rakes without detriment to the work.

MR. BATEMAN: After hearing Mr. Eckersley's previous paper, I feel I must congratulate him on the very excellent way he has re-written his paper to make it both interesting and stimulating in the way he has done to-night. The first thing I would like to ask Mr. Eckersley is having in mind that the machines, even modern machines, are totally inefficient and under-powered for the use of negative rake cutting, does he advocate the use of negative rake fly cutters as a compromise, and as against that, is it any more economical to use negative rake fly cutters as opposed to negative rake milling cutters, having in mind that with the latter expensive cutter regrinding is necessary, and the work holding fixtures required are also costly.

The second point I would like to raise with him is the relative merits of down cut milling as opposed to conventional type milling, that is, using negative rake cutters, and what factors determine by which method the job shall be done when all facilities are available?

Thirdly, can the Lecturer give us any information on the performance of negative rake milling cutters on Austenitic steels?

Finally, would the Lecturer recommend the use of plain tungsten carbide tips on the cutters or those of the mixed crystal grades?

MR. ECKERSLEY: The only justification for the use of negative rake fly cutters is for establishment of data. Throughout this paper I have attempted to stress the necessity for obtaining an economical feed per tooth. The fly cutter is, of course, a single blade cutter, and being such, the feed per tooth is obviously the same as the feed per revolution. If a similar feed per revolution is obtainable economically with a high speed steel cutter, it is not usually justifiable to put a single blade cutter in carbide on the job, at any rate from the point of view of any hoped-for advantage in metal removal rate.

If advantage is possible on an abrasive material by applying a cemented carbide for increased life, then justification is established, but only until a machine can be installed which will enable a multi-blade cutter to be applied to take advantage of the higher feed rate in inches per minute which a modern machine would give. After all, progress in tool design, in whatever form it takes, is demonstrated by the higher metal removal rate of that tool, longer life of the tool

between grinds, and full exploitation of the machine tool during cutting.

Mr. Bateman's question implies considerably more than appears on the surface, and I feel justified in answering his question in the following way:

If a time study is taken on a majority of milling machine production, irrespective of the type of cutter being used, the study will invariable expose that cutting time is a small proportion of the total time during which the machine is running. The application of cemented carbide cutters will only be made by any production engineer if a return in £ s. d. is going to be obtained.

The use of fly cutters can only be made on a low-powered machine or on an old machine, and I question the economy of such applications. I would not apply cemented carbide to any machine driven by a flat belt, neither would I use it on a machine of any age greater than five years, because the machine efficiency in these cases is too low for an economical return using carbides.

Another point bearing on this question of economics is that if the idle time is large in proportion to the cutting time, you will not reduce it by applying a cemented carbide cutter, but you will expose it. There is thus an incentive to apply carbide cutters to a modern machine with high rates of feed available. It is then a function of the factory executive's job to take those steps which are necessary to reduce the idle time thus exposed. There are engineers present who know that on one type of war production in this district, a certain component at the beginning of the war was loaded into a fixture which required the tightening of over 60 clamp nuts before milling started. The clamping and setting operations required about 1½ hours to perform, whereas the milling cut, using high speed steel cutters required about the same time to complete. The application of cemented carbide to this operation reduced the milling time to about one-third, so that the proportion of idle time to cutting time became most noticeable, and induced the application of hydraulically operated clamps to the fixture, reducing the loading time also to about one-third. Maximum machine economy is thus obtained by reducing idle time parallel with the reduction in cutting time, and the application of pneumatic or hydraulic fixtures will assist economical utilisation of machines.

The advantage of climb milling is mainly in the almost uniform chip thickness throughout the path of the blade through the cut, and the increased life of the cutter arising out of better control of tooth loading immediately on impact, whereas conventional milling consists of a condition where the blade enters the cut with a scrape gradually building up to a maximum thickness of chip as the blade leaves the work. The direction of work travel being from left to right, the rotation of a cutter in climb milling would be anti-clock-

wise, but in conventional milling it would be clockwise, and the sketches will make clear the difference in chip formation obtained by the two methods. (*See* Fig. 15.)

The scrape of the blade on entering the cut in conventional milling reduces considerably the life which would otherwise be expected from a cutter. Climb milling, therefore has the advantage of more even loading of the machine, but because of the impact load, the table drive must be designed to cater for this, hence my recommendation in the later part of the paper for the incorporation in future milling machines of a hydraulic screw drive as a standard feature.

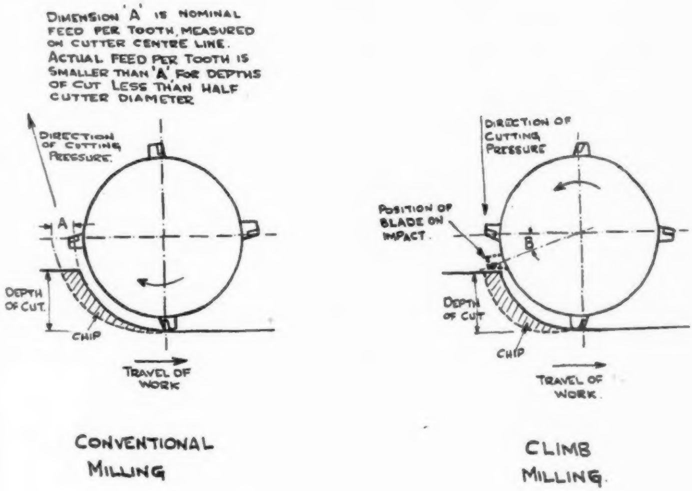


FIG. 15

Choice of rakes is more difficult, however, in the case of a climb cutter if the cutter is required to operate at various depths of cut. Variation of angle " B " requires variation in the measured radial top rake of the blade to produce a correct effective top rake. There is also smaller variation in the feed per revolution required as the depth of cut varies, as compared with the variation in feed per tooth which must be made to attain an adequate chip thickness in conventional milling.

The limitation of machine tools generally installed in factories is that the table feed screw is not provided with means for elimination of backlash, a feature which is essential for climb cutting, so that even though the work-piece may demand milling by climb cutting methods, the machine prevents this operation being carried out, and some sacrifice of cutter life is necessary where high speed tools or cemented carbide tools are used on a conventional milling cut. It is my opinion that the introduction of machine tools equipped for climb milling will eliminate the necessity for conventional cuts to be taken on the majority of jobs.

The experience on negative rake milling of Austenitic steels is very limited, but a considerable amount of turning experience has been obtained with very good results. There is no reason why milling should not be equally successful.

Mr. Bateman's question relative to the choice of tip material is not quite clear, but I presume that the information he is seeking is that a Titanium Tungsten carbide is used on steels as this material provides resistance to build-up on the cutting edge, whereas a straight-forward Tungsten carbide is used on cast iron and non-ferrous metals. Tungsten carbide will not resist the affinity which it has for a build-up on steels.

MR. HARDY : I was very surprised you did not touch upon the vibration curve of the horse-power which has to be applied to eliminate the vibration curve as we know it. Have you any data on which horse-power to apply, and the average depth of cut whereby the vibration curve is eliminated. Then again, you mention vee belt drives. Why not eliminate vee belts and fit a direct drive to give you less vibration ?

MR. ECKERSLEY : It must be clearly understood that all data available from any source on negative rake milling has been obtained on machine tools with considerable shortcomings, preventing the full exploitation of the cemented carbide cutter. The position we are in is that no machine tools are available which will extend a cemented carbide cutter to its limit. It is also very noticeable that the performance of any machine tool on a particular job is very different from the performance of another machine tool of different design on a similar job cutting under similar conditions. These factors ensure an inability to generalise on certain aspects of steel milling, bearing in mind the considerable limitations in feeds possible with the majority of machine tools, available in users' factories.

One purpose of this paper is to stimulate machine tool makers in this country to evolve machine tools capable of extending to the limit the feed rate possibilities of cemented carbide cutters. When such machines are evolved reliable data will be obtainable for general rules to be established.

I certainly mentioned vee belt drives, but in connection with

existing machine tools. A direct drive is, of course, a great improvement on any flexible drive for certain conditions, but if a vee belt drive is eliminated, then flexibility in the shape of a slipping clutch or some such similar device is desirable to provide the safety factor necessary to avoid a breakage of the cutter and spoilage of the work, arising out of carelessness in assessing the metal removal capacity of the machine and its drive.

MR. FOGG: Is it true that negative rake milling with cemented carbide cutters has been introduced because of the physical limitation of the carbide? Is it not also true that progress in cemented carbide development is leading us towards a swing of the pendulum backwards to the normal positive rakes?

The reason for this second question is that I understand development has been carried out in the United States with a material which can be regarded as a successor to cemented carbide as we know it now. If this is true, will it then be desirable to return to positive rake milling because of the better physical resistance to shock of the new material?

MR. ECKERSLEY: It is true to say that negative rakes have been introduced, not because of the physical limitation of cemented carbide entirely, but in order to exploit the cemented carbides. Mr. Fogg appears to suffer the misapprehension which a lot of people suffer, that is, that negative rakes have been introduced recently to provide more business for the manufacturers of cemented carbides. That is not entirely true. I have pointed out in this paper that negative rakes are not new, having been in use on turning for a good number of years. I feel that the correct frame of mind to view this technique is that the introduction of a new cutting material leads to the evolution of a new technique in cutting. Not being a prophet I cannot anticipate what will happen in the future regarding the use of positive rakes, but since this question has been raised, I suggest that an examination of the surface finish of any positive rake tool shows, as indicated on the screen, a surface badly scored and with surface grain mutilation, whereas negative rake produces a clean, shear cut.

It would be a very poor prospect for all of us if we believed that cemented carbides are the last word for cutting metals. Progress will continue and I have no doubt that a successor to cemented carbides will eventually appear, but it would be foolish not to exploit cemented carbides as we know them now, in the hope that something different will come along later which will avoid the necessity for negative rakes. After all, I cannot understand what there is fundamentally wrong with a negative rake which should even cause this question to be raised.

I feel certain that if Mr. Fogg will run tests with negative rakes in his own shops, he will appreciate the advantages in increased rate

of production, and a lowering in the cost of reconditioning his tools and replacement of his consumable tools. It is obviously unwise to treat an experiment as an accomplished fact until the accomplishment is proved.

MR. FOGG: I should explain that the purpose of my question about the return of positive rakes is that if we installed, as you recommend, a machine with considerable horse-power in it, we may find ourselves with machine tools having considerably more horse-power than we can use. A return to positive rakes would possibly mean a return to conventional types of milling machines.

MR. ECKERSLEY: I do not believe in retrogression. The trend is quite definitely towards the evolution of machine tools of all kinds with more horse-power available per machine for reduction in labour consumption per unit of output. We are at this moment in the midst of a revolution in production engineering and production methods. I have devoted a considerable part of this paper to the utilisation of existing machines using cemented carbides, the need for which has been caused by the introduction by product designers of more highly stressed parts made from higher tensile steels. The progress of production engineering lies parallel with metallurgical progress. It is my considered opinion that high speed steel will be relegated, within our life-time, to the archives wherein carbon steel cutting tools and Mushet lie. Metallurgical progress in the evolution of steels which will carry higher stresses obviously requires an entirely different approach from that used on mild steels. A high speed steel tool will not last many minutes on some of the steels used in workpieces even to-day.

The increase in production output from any machine using cemented carbide cutters is in the region of three times that obtained with high speed steel. Surely, when that position is reached, we are not going to return to a condition of limited output per machine tool. The cost per piece produced is the only ultimate measure of production efficiency, and this can be obtained only by increasing the productivity of a machine tool, at the same time reducing the on-costs arising out of the comparison of number of operators used, rent, rates, taxes, etc.

MR. CRUMP: You recommend cutting speeds of about 600 feet per minute for most of the work described to-night, but I have read articles in the American technical press and have had recommendations from other people specifying cutting speeds in the neighbourhood of 1,000 feet per minute. Your recommendations on feeds do not agree with those given by other sources.

MR. ECKERSLEY: The cutting speed used on any job is determined at the maximum speed at which the cutter will run without excessive wear. A cutting speed too high will spark considerably on the work.

The highest cutting speed can be used on mild steels, and about 1,000 feet per minute can certainly be used there, but where a high tensile steel is to be milled the cutting speed should be reduced to about 600 feet per minute for optimum life of the cutter. These figures are based on many years' experience of cemented carbide applications.

It is interesting to compare these figures with the figures obtained on turning with positive rakes. Mild steel can be cut with a positive rake on a turning tool at 1,000 feet per minute up to 1,500 feet per minute, but the higher tensile steels are usually cut efficiently with speeds down to about 250 feet. The reason, in my opinion, for the discrepancy between the cutting speeds on high tensile steels is that a negative rake ,as explained in the paper, produces a plasticised chip which leads to a considerable improvement in the machinability figure under those conditions, enabling high tensile steels to be cut with negative rakes at cutting speeds approaching those used on mild steels, which do not require the plasticising effect necessary in the case of the higher tensile steels. In any case, the effect of negative rakes on mild steel is not at all the same as the effect on high tensile steels. In other words, the condition of a mild steel chip is very little different from that of the parent metal, whereas there is a great difference in the physical properties of a high tensile steel chip as compared with the parent metal.

In considering the recommendations from various quarters on recommended feeds, the differences in machine tools must be borne in mind, but I still stick to the minimum feed per tooth of ·0045" for efficient cutting on most materials. The feed rate available in the machine tool chosen, together with considerations of the work to be milled will determine the number of blades which can be used in a cutter, taking into account also the available horse-power. Usually the maximum feed rate of the machine can be employed on any job on machine tools installed in users' factories. The introduction, however, of new machine tools with feed rates up to 80" per minute which I have recommended, will enable this rate of feed also to be obtained on certain types of work, but roughing on a large range of work will be possible up to 60" per minute.

One general mistake often made is to load a tooth very lightly, leading to wear on the blade because of the inability of the tool to take a bite at the job. Any cut smaller than 0·0007" causes rubbing on a cemented carbide tool, the metal being pushed off instead of being cut.

MR. F. OSBORNE (*Section President*) : I feel there are many of us who will be interested in this question, and I would like to ask Mr. Eckersley if the principle of negative rake milling is practicable economically on cast iron, a material in which many of us will be interested in the near future.

MR. ECKERSLEY: The majority of work carried out on negative rakes so far has been in connection with the milling of steels, and there is not a lot of information available on the subject as applied to cast iron. A fair amount of work has been carried out, however, and so far it would seem that negative rakes are equally efficient on cast iron, but there is no necessity to vary the rakes, of course, as in the case of steels. My own personal preference is for a 10° negative helix angle used in conjunction with no side top rake, but experiments are being carried out at the moment which will establish economic practice on this point.

MR. SYKES: From what I have heard to-night it would seem necessary for every production engineer to have alongside him a chartered accountant to calculate the economics of every application. I have also gathered that high policy is necessary to foresee where improvements in milling by using negative rakes can be applied.

We first of all have to consider the initial cost of a suitable machine, particularly as Mr. Eckersley says he would not put negative rake cutters on any machine older than five years. The initial cost of cutters must also be taken into account, the cost of regrinding equipment, the consumption rate and the cost of regrinding the cutters. The Lecturer hinted that ordinary grinding facilities are not suitable, and I would ask whether edge honing is required in addition to grinding.

There are really two questions in this lecture, and I think the issue is now a little confused.

The first question is negative rake versus positive rake, and the other is cemented carbide versus high speed steel. I think the audience would like some figures given of relative horse-power consumption between negative rakes and positive rakes, because the present cost of electrical power is about 1d. per horse-power per hour, and this is part of the rather complicated calculation which has to be made to decide whether this move is going to be economical or not. With regard to the forecast of machine development, the very wide speed and feed range for maximum figures is very much in excess of what is now current practice. It is a surprise to me that negative rake milling offers any advantage on light alloys, and horse-power consumption is bound to be considerably greater, but with regard to speeds, one previous speaker I think sees a great future in direct drive, and also infinitely variable drives, which has just been the subject of one of this Institution's papers, and offers a promising future for application to machine tools cutting out the intermediate gear drives.

The cost of maintenance of machines with high speeds of say 3,000 r.p.m. has to be very carefully considered. The German machine tool industry developed machines suitable for light alloys

as part of their war preparations, but I am not aware that any of these machines have actually used negative rake cutters of any type, even including the single point tool type.

MR. ECKERSLEY: I am very surprised to hear Mr. Symes' point of view. It has been my opinion for many years that economy in production methods is the Production Engineer's daily lot. I know of no Production Engineer who would even contemplate the necessity of consulting a chartered accountant to assist him in arriving at economical production methods, except in so far as it affected ultimate cost. A works' costing department comprises a very useful department in any factory, and issues routine figures which guide the Production Engineer in a modern factory, as Mr. Symes knows. I am certain that his comments on this point are deliberately exaggerated.

Before any research is started, trial and error methods have usually established a line for research to follow, but we have got far beyond this stage in the application of cemented carbides in this country. The introduction of milling to steels is a natural step forward in the general adoption of cemented carbides for most cutting methods.

In one reply I have made to a previous speaker, I have already mentioned the necessity for considering the cost per component as the measure of production efficiency, and I am certain that Mr. Symes does not run his factory without due consideration of all the factors and expenses which will affect his ultimate component cost. Surely, the correct way to analyse the economy or otherwise of cemented carbides in any form on any job is to find the conditions which will enable that job to be produced cheaper or more accurately that way.

The correct method of conditioning cutters is to use, not a grinding wheel, but a diamond impregnated, metal bonded wheel which gives the best finish to a cemented carbide tool. My criticism of cutter grinding facilities could have been made 20 years ago as related to the regrinding of milling cutters, and still have been a reasonable criticism. As a Production Engineer with experience in many branches of industry, I have invariably found cutter grinding machines to be inefficient and inaccurate, and whilst high speed steel tools have been ground by certain methods for a number of years, it does not follow that these methods should be retained if something better can be evolved.

It has recently been necessary to import from the United States cutter grinding machines capable of reproducing the original accuracy when reconditioning cutters, in order to avoid subsequent finishing operations, either by hand or machine on the component.

A properly finished cutter, using a diamond impregnated wheel, will not usually require edge honing, although a number of engineers

prefer to hand lap the cutting edge prior to taking the first cut with a newly ground cutter.

I cannot give any figures comparing the relative horse-power consumption of high speed steel cutters and cemented carbide cutters, because I believe that very few milling operations exploit high speed steel cutters as far as they might. Alternatively, since the adoption of higher tensile steels for workpieces, the material being cut usually extends a high speed steel cutter to its limit of metal removal rate before the metal removal capacity of the machine tool is reached.

I do not know why Mr. Symes considers a speed of 3,000 r.p.m. one which would lead to excessive machine maintenance. If the machine tool designer knows his job, a machine running at very much higher speeds than that will not require more than the normal attention which any machine tool is entitled to receive. There are milling machines running to-day in this district using cutting speeds of about 10,000 feet per minute using cemented carbide cutters with positive rakes which must always be used on aluminium alloys, as Mr. Symes correctly assumes.

The introduction of recommendations as the basis for design of machines for light alloys was made in my paper for the purpose of comparison in order to establish the point that two types of machine tools are necessary, rather than the sacrifice of considerable attainable efficiency by the use of a general purpose machine tool, cutting materials ranging between aluminium alloys and high tensile steels on the same machine.

MR. F. OSBORNE (*Section President*) : Well, ladies and gentlemen, I am afraid we must now bring this discussion to a close due to lack of time, and it only remains for us to show to Mr. Eckersley in the usual way, our appreciation of a subject so ably presented.

DISCUSSION.

Crewe, 24th November, 1944.

MR. J. MORRIS (*Section President*) : It might be useful to know that in 1926 I made an experiment with cutters from 10″ to 23″ diameter in high speed steels with negative rakes. The body of each cutter was fairly heavy and gave the necessary flywheel effect. The blades of these cutters were pitched at something over 3″, measured on the periphery. One of the jobs done with a 23″ cutter was the lower half of a 30 h.p. engine block in aluminium alloy. The average roughing cuts were $\frac{3}{16}$″ to $\frac{1}{4}$″ deep, and the feed was $30\frac{1}{4}$″ per minute. A finishing cut was taken at $12\frac{5}{8}$″ per minute, producing a surface which was flat to a surface plate. The floor to floor time was about 15 minutes for both roughing and finishing. We had to build two special cutter grinders to deal with the cutters used, and it was

possible on these machines to grind the blades within 0·0001" limits of error.

There has been considerable research carried out in America and this country, all of which has proved that the machine and power available must be adequate to deal with the loads imposed. Secondly, the feed, depth of cut and speed should be co-related.

The flywheel effect mentioned has been known for many years as being necessary to hobbing machines and rotary milling machines.

The geometry of the tool for the work under consideration must be carefully considered, but can be fairly easily calculated, with the basis that the cutting force for negative rake tools must be held not to exceed those for positive rakes. The reason for the apparently paradoxical results for negative rake milling is held to be largely due to the reduction in the co-efficient of friction between the sliding chip and the tool face, and this decrease in co-efficient of friction would appear to be partly due to the reduction in shear strength of the material being cut arising out of the temperature rise and fall.

With regard to Mr. Eckersley's remarks concerning the plastic condition of the chip, the thought arises that when cemented carbides are superseded, the condition of the chip produced might even become fluid.

The meeting will be interested, I am sure, in an unusual application which we have in our factory, using negative rake cemented carbide cutters. Some time ago we found it necessary to mill steel inserts in aluminium alloy castings, and this forced us to abandon the previously used operation of diamond facing these castings. We have now applied negative rake cutters to this job and are obtaining excellent results. It will therefore be seen from this example that when the results of the various researches can be used to full advantage, it will be necessary for planners and jig and tool designers to be fully aware of the considerations necessary to produce all the data for manufacture required by the factory. It is also necessary for works supervision to make themselves acquainted with these factors, and to be able to impart the necessary knowledge to the operators.

My last point is that when we have reduced these cutting times to quite low figures, we must not forget that it will not avail us very much unless the loading times can be similarly dealt with.

MR. ECKERSLEY: I am certainly most interested in Mr. Morris's description of his early experiments with negative rakes on high speed steel cutters. In return, I am sure Mr. Morris will be equally interested to know that cemented carbide cutters are being used today on machines suitably designed to cut light alloys at rates of feeds up to 15 feet per minute. Whilst I do not generally support the application of negative rakes to light alloys, the case mentioned by Mr. Morris is unique.

A light alloy is generally better cut with a positive rake in each direction using a peripheral speed as nearly as possible 30,000 feet per minute, but no machine is available at the present time which will run at that speed. We have a fair amount of experience with cutters running in factories at cutting speeds up to about 10,000 feet per minute, resulting in very high feed rates. In some cases we have actually used the rapid traverse on machines for cutting, and the results have been remarkably good. The limitations imposed by existing machines have led the writer to make the recommendations incorporated in the paper. The only limitation in cutting technique is that imposed by finance which is required to buy new machines to exploit the new cutters. The day will come when cemented carbides, as we know them to-day, are regarded as carbon tools are at the present time. Until that time comes I suggest that we make the best of what we have, at the same time bearing in mind that where replacement machines are being bought it is necessary to obtain machines which will exploit cemented carbides as near the limit as possible, because the limiting factor in machine productivity to-day is not the cutter but the machine.

I am very pleased to hear Mr. Morris's comment on the necessity to do something about work holding devices. I am sure it will not escape the notice of tooling engineers that economic loading appliances are a great advantage.

MR. KNOWLES: Should the number of teeth in a cutter bear any relationship to the diameter of the cutter?

MR. ECKERSLEY: I have explained during the lecture that the diameter of the cutter bears a relation to the width of work being cut. The horse-power input to the machine dictates the rate of metal removal, and as the depth of cut is usually fixed by the work itself the possible feed rate is easily calculated. The feed per tooth can be as high as 0·020", but the figure used will depend on the type of cutter used. Generally speaking, a machine similar to a Milwaukee miller having a 40" feed rate will be able to use a cutter with the same number of teeth as there are inches in diameter of the cutter body.

MR. STOCKTON: Have you found any increase in the heating of the parent metal as the cutter speed has been increased?

MR. ECKERSLEY: If the cutting speed is too high, heat will be produced by surface friction on what should be the front clearance of the cutter blades, resulting in destruction of the front clearance and a subsequent rubbing on the surface of the metal.

Another source of heat in the workpiece is found in a chip insufficiently thick to take away the heat produced in shearing the chip away from the parent metal. Similarly, as explained during the lecture, a feed per tooth which is too coarse will produce a chip which causes excessive pressure on the face of the blade, which will

result in cratering of the carbide and a subsequent generation of additional heat due to the increase in friction between the chip and the face of the blade, and a rapid breakdown of the cutting edge. The correct cutting speed to use is the lowest speed which will produce a first-class finish ; that is, if the surface of the workpiece after being cut is dull the cutting speed is not high enough. If the cutter produces sparks whilst in contact with the workpiece, the cutting speed is too high. The temperature of the workpiece should not be much higher than room temperature.

Given the correct cutting speed, therefore, a cure for a hot workpiece is generally a gradual increase in the feed until the optimum feed is reached. If the horse-power of the motor driving the cutter spindle is insufficient to allow this, a reduction in the number of blades in the cutter will immediately lead to a thicker chip for a similar feed rate in inches per minute of the table.

Mr. Turner : What is the effect of slight chatter on carbide tools having negative rakes ?

Mr. Eckersley : Most detrimental, but, of course, the correct set-up should avoid chatter. There is always a very good reason why chatter is present, for example, I came across a job the other day which consisted of a plate about 3" wide × ¾" thick × 12" long. The 3" width of surface required to be milled. The job was put on a vertical miller with the plate lying flat, and very poor results were obtained, the effect being that the plate acted as a diaphragm as the cutter passed over the centre. The plate, being held in a vice, almost left the vice, due to the vibration set up by the cut. When the job was changed over to a horizontal miller and the plate put on its edge, a very good finish was obtained, with excellent life of the cutter.

Chatter will not come from the cutter itself excepting where the final drive of the machine is through gears which are small in diameter. In that case, a flywheel is desirable to avoid the vibration set up by the intermittent cutting.

Mr. Brooks : I have two questions. The first, have you any information on the performance that can be maintained on negative rake milling over a period of 10 hours ? Secondly, is there any future in negative rake form milling ?

Mr. Eckersley : The answer to your first question depends entirely, of course, on the machine tool used and the rate of metal removal expected. The job shown on the first slide put on the screen is about 3½" wide and 12" long. Seventy-five components are milled per regrind of the cutter, the material being S.11. The floor to floor time on this job is about three minutes. You can work out for yourself, therefore, very roughly the life of the cutter in terms of time. It is impossible to generalise on this question.

With regard to your second question, there have been a consider-

able number of slot milling cutters put into use with excellent results and I am certain that form milling is a practicable proposition given the right conditions, including suitable machines of sufficient rigidity, bearing in mind the length of cut which can occur in form milling.

MR. BARLOW : I think that the high finish obtained with negative rakes is not so much a cut as a burnish.

MR. ECKERSLEY : The finish from a negative rake cutter is definitely not a burnished finish ; it is certaintly a shear cut finish. An analysis of the surface produced by a negative rake cutter shows that there is no deterioration in the physical properties of the material.

DISCUSSION.

Liverpool, 2nd December, 1944.

The Chairman, Mr. J. France, proposed a vote of thanks to Mr. Eckersley for his interesting lecture.

Mr. France invited members of the audience to put questions to Mr. Eckersley, but in the event of there being insufficient time for all the questions, he pointed out that Mr. Eckersley would be glad to answer these by post, and that they should be forwarded to him through the Branch Secretary.

In the meantime he would like to put a question to the Lecturer himself regarding the apparent short life between regrinds of the cemented carbide cutter as compared with that of the normal high speed steel cutter.

MR. ECKERSLEY : The comparison of life between cemented carbide cutters and high speed steel cutters must be measured in terms of volume of metal removed and not in terms of time. It is obvious that if a cemented carbide cutter is capable of a higher rate of metal removal, its life on a time basis might be shorter. Usually, the volume of metal removed by a cemented carbide cutter is considerably greater than the volume of metal removed by a high speed steel cutter. It is also usual that the life in time is longer than that of a high speed steel cutter, particularly where the material being cut has either a greater abrasive action on the tool or the material is considerably harder.

MR. GORDON : Can the Lecturer give an indication of the type or grade of cemented carbide to use with negative rake cutters ?

MR. ECKERSLEY : A Titanium Tungsten carbide is usually used on negative rake cutters for steel. For cast iron and non-ferrous metals, Tungsten carbide is used without other elements.

MR. PATE : How is the life of existing machine tools affected by the new technique, as the machines were not necessarily designed for this method, and it would seem to subject them to excessive wear ?

MR. ECKERSLEY : The technique of negative rake milling has not been in sufficient use over a long enough period to be able to answer this question with any emphasis. It can be said, however, that considering that the machine tool designer has designed his machine to transmit horse-power within the capacity of the motor fitted, it is reasonable to expect that so long as the horse-power of that motor is not exceeded by anything more than the normal overloads there should be no reaction on the machine life provided that excessive negative rakes are not used. The spindle speeds of the machine are sufficient to utilise cemented carbide cutters, and it is usual for the cutting speed employed to be well within the speed range capacity of the machine. Therefore, no trouble should be experienced from that point.

MR. BALSHAW : The Lecturer stated that by reducing the number of teeth in the cutter a gain is made relative to the amount of horse-power required. Are you not, then, approaching fly-cutting conditions, which in our experience tended to cause excessive vibration, which is detrimental to the use of cemented carbides ?

MR. ECKERSLEY : Fly-cutting conditions are only approached when we are actually fly-cutting, that is using one blade, in which case it is extremely doubtful whether any gain would be made by using cemented carbide in place of high speed steel. It is true, however, that a very coarse pitch cutter may require a flywheel fitting to ensure continuous contact between the appropriate flanks on gear teeth driving the spindle. The reduction in the number of teeth mentioned during the paper in connection with the Kendall & Gent CVM.40 milling machine tests, was only taken to a minimum number of five teeth, and no vibration was apparent in this case. The number of teeth in a cutter is to some extent dependent upon the diameter of the cutter. The effect of a small number of teeth on vibration is changed considerably by the actual angle of entry of the tooth into the job. If the tooth can enter the job at approximately 45° to the direction of cut, then the minimum vibration will be set up.

If the cutter is in a position relative to the work whereby the blade approaches the job at 90° to the direction of cut, then an entirely different set-up of conditions obtains, which can be compared with the use of a slotting cutter, either used in a conventional manner or for climb cutting. It will be obvious that the diameter of cutter controls to a large extent the angle of entry of the cutter into the work.

I mentioned during the paper the proportion of 6 : 4 of the cutter diameter to width of work. Visualising a 6″ diameter cutter on work of 4″ width with the cutter placed centrally over the work, there is obviously a 1″ overhang of the cutter on each side of the workpiece. This is the condition which must always apply.

MR. WALSH : Can the Lecturer give some indication of the

accuracy of work produced by this method relative to flatness of surface, etc. ?

MR. ECKERSLEY : The degree of flatness on the surface milled is not dependent in any respect on the cutter used. If the table of the machine operates with any considerable overhang during the traverse of the work there will be a tendency towards the production of a convex face. If the table is well supported throughout its whole traverse, and if there is no end play in the cutter spindle, then flat work will be produced.

It is noteworthy that many factories now employing cemented carbide cutters for milling find they have been able to dispense with surface grinding because the finish obtained is sufficient for most requirements. It can be presumed that in these cases flat surfaces are also produced.

MR. MARSH : Are there any charts issued by the makers as to the recommended feeds and speeds for all classes of steel, when using these cutters ?

MR. ECKERSLEY : The purpose of this paper has been to introduce information to users and prospective users of cemented carbide cutters, which will enable them to obtain maximum efficiency out of their applications. The mere production of this paper indicates that the information contained therein has not been available before. The writer has endeavoured to incorporate information proved in practice, and to avoid any personal opinions or conjectures. Even so, the information which has been given will possibly be found at variance with recommendations made by other people. This is bound to happen where so many people are carrying out investigations. It is therefore only to be expected that no literature or charts are available, particularly when it is considered that the majority of applications in this country are carried out using machine tools which cannot exploit the cutter to its full extent.

MR. BEVERLEY : Why is there not a common grade of cemented carbide for all materials ? What is the necessity for having different grades for ferrous and non-ferrous metals, and what would be the effect of using a grade normally used with steel on a non-ferrous metal ?

MR. ECKERSLEY : Different materials demand different treatment. For example, cast iron is highly abrasive, consequently a straightforward tungsten carbide is used, the high percentage of tungsten providing the resistance to wear demanded by the metallurgical aspect of the material. Tungsten carbides used on steel, however, have an affinity for the tungsten content of the steel, resulting in a " build-up " on the cutting edge, in appearance and texture almost akin to a weld on the chip.

Other materials are, therefore, introduced when cemented carbide

is used on steel to resist this build-up. The introduction of these additional materials results in a hardening of the cemented carbide and the resultant material shows inferior performance on iron and non-ferrous metal to that obtained on steel. The considerable variations obtained in steels require variation in the chemical "build-up" of the cemented carbide used. There are, therefore, usually two or three grades of cemented carbide to suit various conditions imposed upon carbide during its cutting life.

MR. BEVERLEY: Can the Lecturer give some idea as to the efficiency of milling with negative rake cutters, having the teeth stepped ?

MR. ECKERSLEY: I am afraid I am not very interested in stepped cutters. Presumably Mr. Beverley refers to cutters designed with blades arranged around a concentric body and stepped as for height. This type of cutter presents considerable difficulties both in manufacture and in cutter grinding. It is expensive from both angles. It is entirely a compromise design to mill great depths on machines of small horse-power, but the ultimate rate of metal removal is lower than would be obtained with a machine designed for faster rates of feed with several cuts to be taken. In any case, the introduction of such cutters has been entirely special to meet cases which could not be dealt with by more orthodox methods.

A VISITOR: Why are symbols used for the recognition of cemented carbides instead of naming the alloyed elements, in order to give a clearer idea of the use of that particular carbide ?

MR. ECKERSLEY: Because the use of symbols simplifies the identification of grades against a particular application, rather than confusing the operator as well as shop executives, store-keepers, etc., by naming the alloyed elements. It is much easier, obviously, to speak of a "double X" tool rather than Tungsten Titanium carbide. The use of such terms would lead only to considerable confusion.

A VISITOR: Can the Lecturer give particulars of the difference in signs of wear, between a negative rake and a positive rake cutter ?

MR. ECKERSLEY: This question is easily answered. A positive rake cutter would probably break before any signs of wear appeared.

MR. STANIFORTH: What effect will this method have on future machine tool design ? Can existing machines be fully utilised, or will it be necessary to design new machines ?

MR. ECKERSLEY: It is always necessary to design new machines. I had hoped that the paper would make it quite clear that existing machines can certainly be fully utilised, the major part of the paper having been devoted to explanations of limitation in feed and horse-power. This is not to say, of course, that it would not be more economical to install new machines specially designed for this

technique. It should be recognised that we are in a transitional period between high speed steels and cemented carbides equivalent to that at the beginning of this century when carbon steel tools gave way to " Mushet " and its successors.

MR. GORDON: What is the recommended depth of cut when grinding cemented carbides ?

MR. ECKERSLEY: Only just as much as is necessary to recondition the tool. The cutter should not be driven so long in work that the cutting edge requires considerable treatment in reconditioning the cutter. It is best to take a cutter off work immediately re-lapping becomes desirable. The cutter life is thus prolonged because the minimum amount of carbide has been removed each time it has been found necessary.

MR. HARRIS: Are negative rakes recommended for use in machining aluminium alloys ?

MR. ECKERSLEY: Definitely not. A positive front top rake or helix angle of 12° and a positive side top rake of 12° have been found to give optimum efficiency on aluminium alloys. The exception to this rule is in the case of a component in aluminium alloy with high tensile steel inserts. In this case, a negative rake cutter is used, but with a very shallow depth of cut, and the resultant finish is very good indeed. The surface of the steel inserts is dead level with the aluminium body.

DISCUSSION.

Blackburn, 13th January, 1945.

After opening the meeting for discussion, MR. THOMPSON put the following questions :—

1. Is there any difference in the performance of inserted blade and solid milling cutters ?
2. What is the difference in chip form produced by a high speed steel cutter compared with the carbide cutter with negative rake ?
3. Can the negative rake principle be applied to the milling of slots and, if so, would Mr. Eckersley recommend normal or climb milling for this purpose ?

MR. ECKERSLEY: 1. As a rule a correctly designed inserted blade milling cutter will produce more components per regrind than a solid milling cutter will of the same diameter and with the same number of teeth cutting at the same feeds and speeds, but I cannot account for this difference in performance.

2. A high speed steel cutter produces a chip which is relatively

tightly curled to a smaller radius as compared with the chip produced with a carbide cutter having negative rakes. In the latter case the chip leaves the job at a point on the component much closer to the cutting edge than is the case with a chip produced by a high speed steel tool. In other words the chip produced by a high speed steel tool makes first contact with the cutter at a point well away from the cutting edge, whereas the point of fracture of a chip produced with a negative rake is considerably closer to the cutting edge and the chip is in contact with a fairly considerable area of the face of the carbide tip.

3. The milling of slots is already an accomplished fact, using cemented carbide cutters, but as the majority of machine tools are not equipped with means for elimination of feed screw backlash it is not always possible to apply climb milling principles to those jobs which could employ climb milling with advantage.

I have recommended in the paper the incorporation of automatic backlash elimination by means of a hydraulic screw and this feature would enable a milling machine to be used on climb milling wherever the job justified this process.

It is my considered opinion that the milling machine of the future will reduce to a very small number those jobs milled by what is now known as conventional methods, that is with the work travelling from left to right, the cutter rotates in an anti-clockwise direction when looking towards the spindle of the machine.

Mr. Brierley : 1. What is the cost of a cutter similar to the one on view ?

2. What time is required for re-sharpening after use ?

3. It appears to me that with the very rapid rates of traverse the major problem is not milling the job, but handling the job.

4. What is the comparison in the number of components per grind obtained with a high speed steel cutter and with a negative rake carbide cutter ?

Mr. Eckersley : 1. The cutter on view is a 6″ diameter face milling cutter having eight teeth and the cost is about £29.

2. Re-sharpening time should be a matter of 15 minutes to half an hour in the case of a cutter having had normal use up to the point of re-lapping being required. Use of a cutter beyond that point increases regrinding costs considerably and therefore reduces the advantage gained in applying the cemented carbide cutter.

It will be found that using a cutter up to the point when the horse-power consumption begins to increase will give an economic return on the application.

It should not be necessary to use anything other than a diamond impregnated metal bonded wheel for re-sharpening.

Mr. Brierley's third point is a very important one. When a reduction in cutting time has been made exposure of inefficiencies in handling invariably appears. The use of pneumatic clamping devices on work fixtures can do much to increase the economy of machine tool utilisation.

It is very difficult to give a generalised reply to Mr. Brierley's fourth question, but I will say that three times to ten times the number of components per regrind of the cutter is obtained with a cemented carbide negative rake cutter on steel, as compared with the number of components obtained from a high speed steel cutter.

MR. EATON: Could Mr. Eckersley give me some information about negative rake milling on cast iron?

MR. ECKERSLEY: Experiments have recently been carried out with negative rakes on cast iron and they would appear to justify the use of negative rakes from the point of view of the increased feeds possible and increased life of the cutter, but these tests have not been carried out on flimsy components and I cannot say at this stage whether or not light components, such as those used in textile machinery or printing machinery construction, could justify the use of negative side top rake. A negative helix angle is, however, definitely recommended because the same conditions of impact loading apply to a milling cutter irrespective of the material being cut. I trust that within a very short time performance figures will be available for the use of production engineers requiring information on the milling of light cast iron components.

MR. BOARDMAN: Regarding negative rake cutters on steel, I admit that we have had most wonderful results, but there is one snag; that there is disintegration of the tip. What is the cause of it? It is not flaking, it comes off in the form of dust.

MR. ECKERSLEY: The only reason I know of for disintegration of cemented carbide is the overloading of the tip, resulting in excessive pressure, which will crush the binding element used in the manufacture of the tip.

A similar condition can be caused by over-heating of the tip during grinding, caused by too much pressure during the grinding or insufficient water being used.

The result of such conditions will cause fine surface cracks in the tip which will give the appearance of tip disintegration immediately the tool is put to use.

The production of heat cracks such as those described results in the complete destruction of the tip as a useful tool.

A VISITOR: You mentioned the fact that heat generated from negative rake milling is used to plasticise the metal. What happens in the case of air hardening steel?

MR. ECKERSLEY: Air hardening steel is only hardened immediately

the source of supply of the heat is removed, so that during the actual partition of the chip from the parent metal heat is continually flowing into the chip until it leaves the workpiece, when on exposure to the air the chip is hardened.

MR. RYDER: Would Mr. Eckersley justify the very high rate of feed which he advocates machine tool designers should provide, in view of the fact that his experience up to the present apparently ranges only up to 40" per minute.

MR. ECKERSLEY: Many figures of feed rates in inches per minute beyond 40" have been published in the technical press, representing production performances both in this country and in America, but the figure of 80" per minute which I have recommended as being possible could no doubt be exceeded if suitable machine tools were available. This figure is, however, affected by the necessity for economy in machine design to some extent, but simple calculation taken after experience of tooth loadings on feed rates within the capacity of existing machines, together with the knowledge that the pitch of cutters used can be lessened, shows that cutters which have been used at 40" per minute could be fitted with twice the number of blades, so that for equivalent tooth loading already proved economical, a feed rate of 80" per minute is easily attainable.

DISCUSSION.

London, Friday, 13*th April,* 1945.

THE CHAIRMAN said the paper had been most informative, and dealt with a subject which was very much in the minds of most production engineers. The limitations which could be implied from what the author had said should give rise to a considerable amount of discussion. The author had mentioned some of the limiting characteristics of machine design and had given a tentative warning with regard to application without expert advice. The paper should make it possible to decide where one could begin to apply the principles with which it dealt and where it would be advisable to apply for expert advice.

MR. BLACKSHAW, in opening the discussion, said he had listened with interest to the author's remarks, and some of them left him almost breathless.

He would like to ask whether it was the author's considered opinion that negative rake milling had now reached a stage where it could be said to be a definite economic proposition. It was possible to give wonderful results showing what could be done, but completely to forget all about ultimate machine maintenance, the high cost of re-grinding the cutter, and so on.

MR. ECKERSLEY said his reference to a figure of 240 inches a

minute had been made in relation to light metal alloys. He had successfully applied a rapid traverse of 15 ft. per minute to milling as a production job. It might be of interest to mention that in 1932 the English Electric Company, of Stafford, took out the segments of a grinding wheel on a Lumsden horizontal grinder and put in aluminium blocks carrying carbide tools for machining crank-cases. What the grinding feeds were like on a machine of that description was well known. A cutter under those conditions was running for a fortnight with a feed rate of 16 ft. per minute as a production job. It was stopped by the Home Office, who considered it to be dangerous. They had reverted to those feeds during the war, on heavy bomber production in particular, where the length of work reached anything up to 40 ft., and if the war had gone on much longer he was sure machines would have been made available to reach the figures he had proposed. Machines were available now with fairly high rates of feed, but not up to that figure. The maximum rate of feed was determined, as Mr. Blackshaw rightly assumed, by the ability of the operator to keep pace with the job.

The economics of negative rake milling were definitely established, particularly in those shops where there were some really able jig and tool designers who were capable of designing tool equipments which would reduce considerably the idle time of the machine in production ; and, of course, the performance of any cutter was bound up with the economics of the total cycle time of the machine as related to the cutting time.

He could give very many examples to prove his point. In the North of England there were very many shops which were fully tooled with negative rake cutters of all kinds. The Merlin engine con-rod was fully tooled in one factory with negative rake cutters on standard machines of American design, and in some cases a considerable advantage was obtained in floor-to-floor time, while in other cases the application was made purely from the point of view of economical cutter life. With a high-speed steel cutter, for example, on an 80-ton material, a change-over might have to take place every hour, but when a carbide cutter was used an 8-hour run might be obtained, with resultant economy in the turn-over of the machine.

Mr. Beswick, who mentioned that it was some fifteen years since he had spoken at a meeting of the Institution, put two questions to the author. The first was whether he had had any similar experience of negative rakes in connection with surface broaching. If so, it was his personal view, knowing what he did about surface broaching, that some very phenomenal results could be expected from that process. Secondly, where steels were of a work-hardening nature, did the author find any tendency to surface hardening ? One would rather expect that, because there must be considerable compressive

stress immediately in front of the tip on the material. If that did take place, it might be an advantage in some cases, but in others a very serious embarrassment.

He was particularly interested in the author's statement as to the economic speed being the speed at which no heat remained on the workpiece. He remembered in 1937 having a long discussion with Karl Peters' in Berlin, who advanced the same theory, which no doubt was fairly generally held and not his own discovery, and said that when he had a tool to build to produce a piece (because they built their tool to the piece) his first experiment was to determine the cutting speed, and his theory was that it was that speed at which the chip took away all the heat. Peters had a very ingenious arrangement for thermometric work, whereby he said that he was able to prove that there was an economic limit ; when one got above a certain speed, more heat was created that the chip would take away and the curve began to fall again. He determined that, and then, having had it laid down by an even more autocratic body than British engineers had to deal with in these days that he was producing a machine to produce so many pieces per hour, he worked out his horse-power (which was fairly easy to do) and was surprised to find that he required over 80 h.p. for a machine normally requiring 10 or 12 h.p.

That was in 1937, and personally it had been a great grief to him, having come back to England, and in 1940 being endowed by the Government with a plant to do a similar job, with multi-cut tools and carbide-tipped tools, to find that while the Germans had a power of over 80 h.p., this plant was equipped with a 12½ h.p. motor.

That was borne out to some extent by the author's remarks as to the greater power absorbed by American machines of well-known types over any produced in this country. He did not want to say nasty things about British machine designers—he knew too many of them—but it did seem that in machine design in this country we had fallen steadily behind, and to-day it was necessary to go abroad, and in the near future he could foresee having to go abroad, for quite a number of machines which one would very much prefer to see produced in this country.

He was very pleased, in view of those considerations, to see that the author and his colleagues had actually been producing some fundamental, basic data on which machine design could be initiated, because that was the way to start ; it was from the author's charts and curves that one wanted to start designing machines, and not, as in the past, find that it was convenient to install a 12-h.p. motor and therefore say that the machine must be powered by 12 h.p.

MR. ECKERSLEY said it was obvious that Mr. Beswick was a man after his own heart. Mr. Beswick was ahead of him on surface broaching ; so far, he felt that they had quite enough to do to con-

vince production engineers generally that negative rakes were economical at all. The next step, without any doubt, would be in other directions. It was well known that before the war the Cincinnati Milling Machine Company in America carried out tests on surface broaching, using cemented carbide broaches. He was certain that that arose out of the fear of the complete eclipse of milling as a production process on large quantity work. Surface broaching had made rapid strides in the last few years, and many people used it as a regular production process. Unfortunately, however, the cost of a cemented carbide surface broach was often almost prohibitive, because of the limiting factor which then had to be considered in changes of design of the product, so that another economic factor entered into the picture which would to a large degree mean that milling would hold its place for many years to come, he was certain, utilising cemented carbide cutters.

They had made quite considerable headway in the manufacture of components in work-hardening steels, using negative rakes. Curiously enough, the fact that negative rakes were being used did not appear to contribute work-hardening to the job. It was true to say that where a work-hardening steel had to be machined, the biggest factor affecting work-hardening was the inherent rigidity of the machine itself, the freedom from float in the cutter spindle and the completely rigid hold of the job. Work-hardening, in other words, came from the relation between cutter and work which would cause rubbing at some point in the action of the cut, resulting in local work-hardening, which prevented the cutter from taking another bite at the job.

MR. FRANCIS raised the question of the relationship of accuracy to finish. He had heard various degrees of accuracy quoted, he said, as being necessary, from 0·0001 to 0·002 inch. If they were to be faced with cutters with an accuracy of 0·0001 inch, he imagined that many of them would be in for some headaches. The other point of interest was whether there should be a land on the face of the cutter.

MR. ECKERSLEY replied that the accuracy of a cutter need not be more than the cutter grinder could produce. After all was said and done it was necessary to fix some basis of error. In view of the fact that the manufacture of the cutter itself in the first place demanded some margin of error, it was only to be expected that the manufacturers of the cutter would condone some inaccuracies in the re-grinding of the cutter, and he felt that a figure of about 0·001 inch was fairly reasonable.

There were some samples of finish on the table in front of him. There was one piece of mild steel, a piece of steel of about 80 tons per sq. in. tensile, and also a piece of cast iron. The steel had been finished with a trailing edge, which was what they called it in the trade ; not a land, but a trailing edge, where the finish had to be

fairly high. The object of that was to avoid subsequent grinding finish where accuracy was not in question. Where it was a matter of finish only, that finish could be obtained by using the trailing edge, but where normal milling was required merely for metal removal, the trailing edge was not so necessary ; it was sufficient to remove metal if finishing was going to be carried out as a subsequent operation. If the samples were examined afterwards he thought it would be agreed that the finish on them was as good as would be obtained from some of the war-worn surface grinders which it was necessary to use to-day.

MR. CLARKE asked whether the author had any information on the application of negative rake milling to other than metallic materials. He had in mind some of the grades of Bakelite and some of the grittier grades of war-time insulators. His own firm had attempted to carry out some experiments in that direction with one particular job which was giving them a very great amount of trouble. The material in question was a grade of ebonite, containing a very high proportion of gritty filler. They found that the best method was to use high-speed cutters, which would give a certain production, but they did not find it possible, in spite of all their efforts, to get a cutter to stand more than one day's work. They decided, therefore, to try a carbide cutter with negative rake and note the result, and so they made the cutter and applied it at a feed rather more than double that which they had previously used. They found that after about a week they were still able to maintain the limit, which was, incidentally, a very close one. They let it run for another week, and they still could not find any trouble, and in actual fact that cutter ran continuously for four and a half months before they had to touch it.

MR. ECKERSLEY expressed his pleasure at hearing what Mr. Clarke had to say, and said he would like to explain why the result in question was obtained. The reason that a positive rake cutter broke down on any synthetic material or any abrasive material (and synthetics of the type in question were highly abrasive) was the way that the chip came off, and there was a cratering effect due to the highly abrasive nature of the material. That caused, in addition, a fall of highly abrasive dust which accumulated in the cavity, and as the cutter revolved it dragged over a pile of dust in the bottom of the crater, and that wore off the front clearance, so that one got wear on the front clearance and wear on the cutting edge.

The reason why the negative rake was successful was entirely different from the reason why negative rakes were successful on steels and iron ; it was because the chip came off as a flat chip and was in contact with a very large area of the tip, so that there was no cratering effect. Carbide was the most highly resistant material known, apart from the diamond, to wear. It would withstand the wear, and the chips came off at a faster rate in the direction indicated

than in the other, because of the width of the angle of shear, and one did not get dust dropping down ; it was carried up with the chip itself. It was very curious that negative rakes would give similar results on a material of that kind to those obtained on steel, but for an entirely different reason.

Mr. Marsden wished to raise a small question, but one of importance to a great many people. The author had said that the quality was good, and no doubt it was ; but how deep was the quality ? Was it of the order of 6 or 66 microinches or was it a smear, and was it amorphous metal or good base metal. That was important, because they were concerned with the wearing qualities as well as the finish.

Mr. Eckersley produced some microphotographs taken in a laboratory as part of a series of laboratory tests to analyse surface destruction. The finish which could be obtained under the very best conditions on a steel which was suitable to give a high finish was in the region of about 3 to 4 microinches, normally. Three first-class factory laboratories in the North of England had made surface analyses, chemical, physical and metallurgical tests, which would indicate that there was no destruction of the surface structure and there was no distortion of the grain. In other words, there was considerably less effect on the surface of the material than was obtained with the orthodox high-speed steel cutter.

In proof of that, apart from milling he could list at least a dozen turning applications using negative rakes at this moment on components which were very highly stressed, as, for example, aero engine valves, where there was no bad effect at all on the skin surface of the material. There might be materials which would be effected, but he had not met them yet.

Mr. Gilbert said his firm were very interested in the use of negative rake tools. They could bear out the author's information with regard to the maintenance of tools. With that in view, they had been to some trouble to make provision for the correct servicing of cemented carbide tools, not only of the normal rake, but also of negative rake. In view of the fact that machine-tool manufacturers were very hesitant to produce a machine suitable for taking the imposed strain of negative rake milling, and also turning, they were carrying out a few experiments themselves in machine-tool design. He would like to ask, therefore, whether the author had any information with regard to the thread milling of components with negative rake cemented carbide cutters.

Mr. Eckersley thought that that came under the same heading as surface broaches, and said that they had not got as far as that. because there were inherent difficulties in producing a cutter of that type with a cemented carbide tip which was going to be economical.

It was undesirable to be complacent about the success of cemented carbides to-day. Just as cemented carbide was the successor to high-speed steels, so no doubt there would be a successor to cemented carbides in the form in which they were known to-day, and he felt that it was that successor to cemented carbides which would show to most advantage on applications such as thread milling Taking those factors into account, he thought it would be a long time before thread milling was used in conjunction with negative rake cutters. It was interesting, however, to note that an operation akin to thread milling, namely, profile milling with bigger forms than on the normal screw thread, was very successful, using a hob and a flywheel built into the machine.

MR. GILBERT said the main trouble which the author seemed to have in mind was the fact that the pitch of the thread necessitated very careful handling of the grinding of the hob. In the case of a tap used on tubing, it was normal practice to use an interrupted thread tap, *i.e.*, a thread which was interrupted to give one crest and then a gap and then another crest. To produce a thread milling hob having an interrupted cut similar to a tap would be much less difficult than to produce one with a full thread. The author stated that most thread milling was of a short cycle time, but with diameters of 4 and 5 inches it was not always a short cycle time. Furthermore, there was a fairly good chance of a robust cutter of, say, 4-in. diameter which he felt could be exploited by someone with sufficient facilities. It was with that in view that he had mentioned the matter, inasmuch as many people had thread milling problems, and he felt sure that if the expert advice which had been promised was forthcoming there might be developments along those lines.

MR. ECKERSLEY replied that Mr. Gilbert no doubt realised, and in fact had said that he realised, the difficulties of designing a cutter. It obviously required very special consideration and design for the actual job in hand. He saw no reason at all why a job of that kind should not be got on with from the point of view of experiment only. It was a matter of development, and, if Mr. Gilbert's company could afford the development, that was all to the good.

MR. HEMSLEY mentioned, for the author's information, that there were already tungsten carbide thread milling hobs on the market in America, and that experiments were taking place in this country with Stellite thread milling hobs.

MR. ECKERSLEY said the fact that cemented carbide hobs were on the market was no indication of the degree of success which they had reached in their application. He would like to point out that negative rake milling cutters were on the market in America long before they were on the market here, but there had been considerable alterations by the time such cutters were on the market in this country. The fact

that there were thread millings hobs available did not, to his mind, justify their application. There were very serious inherent difficulties in the manufacture of cemented carbide hobs which in this country made them tend to be uneconomical. There were a few organisations in this country which had the quantities to deal with which the Americans had, and those organisations which were so fortunate as to have continuous runs were justified in carrying out experiments, but he believed that from the manufacturers' point of view the consumption of cemented carbide thread milling hobs in this country was not sufficient at the present time to justify any considerable research which would develop hobs for normal production work. Each case required to be taken on its merits, because it was an operation about which one could not generalise, as one could in milling.

There was a tendency for store-keepers to issue a hob of the correct diameter and pitch to the shops, irrespective of the material for which it was to be used, and one could not afford to risk mistakes in the issue of cemented carbide, because it was too expensive. There must be a developed production method, and so far there had not been anything like the research carried out which would justify anyone embarking on the manufacture of hobs as a going concern. He doubted very much whether the Americans had gone far in that direction; they might have them on the market, but that was a different matter.

MR. ATLEY asked whether it was the author's experience that with the use of negative rake milling cutters better results were obtained with climb milling than with conventional milling.

MR. ECKERSLEY said he had been waiting for that question. It was his considered opinion that, provided the machine tool was properly designed, climb milling was without any doubt far superior in its performance results to orthodox milling. The main reason was, of course, that in orthodox milling the cutter was feeding forward into the work and revolving upwards in its approach to the work; in other words, the commencement of the cut in orthodox milling was the feather edge, gradually increasing to something thicker, whereas climb milling gave much more nearly a uniform chip thickness throughout.

MR. REDFERN said that having had some experience of this type of milling, one of their troubles was the cutter dragging, and very few of the machines which he had seen had the necessary heeling to counteract this. Furthermore, gear-cutting was as a rule a long operation, and it would therefore be interesting to know whether the author had any ideas on hyper-milling. He could have a hob made up in tungsten carbide for it, but he could not get the speeds suitable for hyper-milling.

MR. ECKERSLEY explained that the standard horizontal or vertical miller was required to operate in either direction, and that was why there was no heeling of the head. It was standard practice in machines of the planer-miller type, where feed was in one direction, to pitch the head so that the front of the cutter cut, and the back of the cutter was relieved by an amount of about 0·001 in. in 12 in. There were milling machine designers to-day who were considering the advantages of heeling, so that cutting was in one direction only.

With regard to the question of gear cutters, experiments were now going on on the application of negative rake cutters to hobbing gears, both cutters of the orthodox hobbing type and cutters of the Sunderland type. The Fellowes type so far had not been touched, but they might be at a later date.

MR. KIRCHNER, reverting to Mr. Blackshaw's point about the economics of negative rake milling, said Mr. Blackshaw did not put the question so specifically as he himself would like to do. Mr. Blackshaw asked whether negative rake milling had come to stay, and the author was apparently quite definite that it had. Personally, he wished to ask whether the author's opinion was based on the fact that there were many manufacturers, and particularly large manufacturers, in this country who were using it on a wide scale, and that therefore it was reasonable to assume that they had satisfied themselves that it was worth while, or whether it was based on the detailed economics of the question.

After all, the period of the last five or six years was not a very good time to judge whether a particular operation was sound economically, because there had been only one customer. Taking the different conditions of the post-war period, with the question of export competition and so on, was the author satisfied that, bearing in mind the fact that it was necessary to use heavier and therefore more expensive machines, which would probably have a shorter life, and bearing in mind the increased initial cost of the cutters and the increased cost of their upkeep and the greater risk of damage, was negative rake milling economic ?

So far as the increased cost of upkeep was concerned, he understood from information which he had seen that the cutters did not necessarily last longer than high-speed steel cutters, but there was a quicker rate of output with their use. The greater risk of damage was a point which had not been made altogether clear. He understood, for instance, that if a cutter was stopped during a pass across a job there was considerable danger of the teeth being chipped. He could also imagine a cutter being quite easily damaged by one of the usual milling machine operators deciding that he would see what happened if it went a little faster ; in other words, if he stepped the feed up. A cutter might be designed for a certain speed, and the milling machine operator might think it could be run half as fast

again, and he would try it to see what happened. What would probably happen would be that the teeth would go, and damage to the extent of about £25 would have been done.

Another aspect of the use of negative rake milling from an economic point of view was that it was not going to be much good in most cases unless there was much more elaborate tooling. He had seen two very good demonstration set-ups in the Midlands, and in order to secure the benefits of the saving in cutting time, it was necessary to introduce some equivalent reduction of time in loading and unloading by air operation and so on, so that a fixture which was originally a base and a couple of normal clamps became quite a complicated mechanism for air operation, and the cost of tooling also went up.

Reverting to his original point, in the last five or six years the only object had been to win the war, and if it had been possible to get a job done more quickly cost was a secondary consideration, but a time was coming when it would still be desirable to get a job done quickly, but if that was going to add greatly to the cost it would not be possible to afford it. Also, it was reasonable to assume that there would be more labour available. He would like to hear the author's views on the matter, and whether the author had really gone closely into the question of pounds, shillings and pence.

Mr. Eckersley said the best reply he could give on the question of the economics of negative rake milling was to point to the fact that some of the railway shops in the North of England found it economical from the point of view of cutter cost and cost per component to use negative rake cutters. The way in which a railway shop was run was very different from the way in which many factories were run. The railway shop was at the mercy of repair gangs who wanted one of this and one of that, and even their production batches seldom exceeded four, and the similarity between one component and another bore no relation at all to the loading of machines. Locomotives were built one at a time, or alternatively if there was a line of locomotives, which was the best that they could aim at, the components which went to make up a locomotive were made not more than three or four at a time, with the result that a milling machine could on one occasion be set up with the long connecting rods and on another with some very short brackets of some description.

The railway shops to which he referred had recently been using modern machines of the American type, Milwaukees, and they obtained excellent results. Their measure of economy was on the basis of cost per piece, and they found that the manufacturing cost per piece was less using carbides than using high-speed steel. That was due in the first place to the fact that they got a better output ; their rates of feed were far higher than with high-speed steels. Secondly, the horse-power consumed per cubic inch of metal removed

was very much less with carbide than with high-speed steel tools. Thirdly, they used fewer machines for the same output, and, taking an analysis of the usual incidentals which contributed to on-costs and overheads (floor space, lighting, and so on) they were definitely satisfied that they should go ahead with as many applications as possible of negative rakes.

At the other end of the scale, the Ford factory had tooled up every steel job they had in their shops, and Ford would never embark on any enterprise involving a fairly large change in production methods unless it was economical.

He had not taken any figures out himself, for the simple reason that the economics of any shop were individual to that shop, and it was not possible to generalise. The production engineer of any factory must satisfy himself that the conditions in his shop were suitable for the economic exploitation of cemented carbides. It might be mentioned, however, that identical questions were raised in 1926, 1927 and 1928, when the original cemented carbides came to this country for use on turning and other very simple operations. One must remember the evolution in machine-tool design which had taken place as a result of that as applied to lathes and similar machines. He suggested that a similar period was now being gone through with regard to milling machines, because the application of cemented carbides had been taken a stage further.

He knew that Mr. Kirchner did not wish to be at all retrogressive, but was searching for a yardstick by which to measure the possible economy ; but personally he felt that at the present stage, even with five years of war experience (which was equivalent to ten years of normal production experience), plus the pre-war experience of carbides, they had still touched only the fringe of the possible applications for cemented carbides, both as metal removers and as giving resistance to wear. He felt, therefore, that it was rather early to give an answer on the question of economics, when there were not two shops in the country with similar problems.

Mr. Selby said the author had made some adverse criticism on machines of British design, and he thought that something should be said on the other side. In the first place, it should be borne in mind that rationalisation in this country had held up the development of any machines during the last few years, much more so than in America, and it was during those few years that the trade might have taken some steps to meet this development. With regard to the statement that machines should be made to transmit the necessary 50 h.p., even though provided with a motor of perhaps 10 h.p., he thought that a 50 h.p. machine would obviously require gears of five times the width, and therefore the castings and columns would have to be proportionately bigger.

One problem which arose in designing machines suitable for

negative rake milling concerned the driving of the spindle, and he thought that the author might have been able to offer some suggestions in that direction. The author had stated that in his experience the cutting of aluminium alloys could be done by a Lumsden grinding machine. In that case, apart from the advantage obtained in quick traverse rate, an even greater advantage would be obtained by virtue of the fact that the spindle was usually driven by a stator-rotor unit operating the feeder with gears with high meshing speeds. In the case of hyper-milling, since the gear should presumably be at least equal in diameter to the largest cutter which was to be used, one might expect that a gear of 12-in. diameter would be necessary on a machine of medium size. With a 12-in. diameter cutter operating at about 800 ft. per minute, that would give a speed of 800 ft. per minute, which would be reasonable ; but if the same machine was to be used with a hyper-milling cutter of about 2-in. diameter there would be a meshing speed of about 5,000 ft. per minute, which would presumably be quite impossible under present conditions.

It was well known that in the case of light alloys machines had been built to use stator-rotor units or belt drives, and in the instance under consideration he thought that the only solution would be to come back to belt drive, with perhaps a system of back-lock, so that one would use belt drive with a large diameter pulley for small cutters and with large cutters get the advantage of gear reduction.

Personally, he thought that the delay in providing suitable machines in this country was only temporary, and due to circumstances, and that the leading manufacturers would very shortly show what they could do. In the meantime, however, he would like to have the author's opinion on the problem.

Mr. Eckersley said that he himself, like many others, had been a victim of rationalisation. It was recognised and accepted that the British machine tool maker had certainly been handicapped during the war. He himself had made no recriminations against British machine tool makers—it was members of the audience who had done that—because he happened to be associated with a machine tool company and knew the difficulties which had to be faced by machine tool makers. He felt, however, that the time had come when machine tool makers had to face the prospect of having to re-design their machines, and it was obvious that Mr. Selby agreed with him there ; and, in agreeing with him, he was half way to solving the problem of re-design.

In considering the size of gears on a machine intended for ferrous machining, the point that Mr. Selby made was an important one, in that the relation between the size of gear and the size of cutter had a certain importance. The usual practice in selecting a cutter diameter was to take the front bearing diameter of a milling machine and multiply by $1\frac{1}{2}$, and that gave the maximum size of cutter which

should go on that machine. When relatively high speeds, such as 700 ft. per minute, were being used, it was necessary to consider the driving gears, as Mr. Selby rightly pointed out, and if the main driving gear on the spindle was smaller in diameter than the cutter which was being used there was considerable mechanical advantage in favour of the cutter, and satisfactory contacts between the meshing gears on the main spindle drive could not be maintained.

It would be recalled that in his recommendations he had mentioned that a flywheel should be built in on the machine. His company already had considerable experience in the application of flywheels for very much higher speeds than had been normal on machines in the past, and they found it very successful. As a matter of interest, a friend of his who had a factory in Liverpool, and who had helped him considerably with experiments, took out of the production shops a very old milling machine to see what happened when he put one of his carbide cutters on a job. There was 0·015 in. of end-play on the spindle front bearings, and there was a lot of slip in other places as well. The cutter did not make one revolution before teeth started to be ripped off, but he built a flywheel on that machine and within a fortnight, on the particular job which he had on the machine, he had not re-ground the cutter once, and his rate of feed was the maximum that the machine would take. The flywheel was a very heavy one, but it actually succeeded in disposing of all the effects of the end-play and give a really good finish on the job. Personally, he did not know how long the machine would stand up to that, but the flywheel absorbed all the bumps on the job. The main driving gear on that machine was about 8-in. diameter, and a 6-in. cutter was in use.

In considering the type of drive to a machine which was going to run at very high speeds on light alloys, he suggested that the maximum speed at which the designer felt it safe to run the machine continuously should be a fixed speed. It had been suggested in some quarters that a direct motor drive would suffice. That had its disadvantages, but he felt that Mr. Selby was on the right lines in suggesting perhaps a V belt drive as a compromise. There would be a certain resilience in the drive which was valuable. He did not know enough about electric motors to be able to say whether or not a direct drive would be a wise thing when a carbide cutter was running at a high speed.

He had suggested a 50 h.p. motor on a machine of 18 × 72 table size, but he was sorry if he had implied that a 10 h.p. motor might be used on that. In the paper he had said that machines were usually chosen for table capacity rather than metal removal capacity, and he had also said that milling was the least understood of all machine shop processes, as a walk through their own shops would show people, if they really got down to brass tacks on most applications.

Where he suggested the 50 h.p. motor, in the case of the machine shown on the screen, he did not think that that machine should be put out with anything less than 30 h.p. on it, but there was not a great deal of difference between 30 and 50 h.p. from the machine tool designer's point of view. It had been standard practice for many years with certain machine tools to design for the maximum horse-power that the machine would take. Where most of the controls and changes were electric, the cost of the machine tool was relatively unaffected by the horse-power which it would transmit. He felt that machine-tool designers had to tackle the problem from an entirely new point of view. They had to forget all about Norton gearboxes and the normal change-speed methods and evolve something different which would allow the machine to be used flexibly in its application to a variety of products.

MR. BLACKSHAW, who proposed a vote of thanks to the author for what he described as an interesting and provocative paper, said the author had revived an interest which he once had in the subject, but had allowed to flag. They had said to themselves that there must be something in it, and they spent £48 on a cutter, but an hour later Mr. Judson came to him and said " It's gone ! " He had brought Mr. Judson to the meeting that night to try to revive his interest, because personally he still felt that there must be something in it.

The vote of thanks was carried with acclamation, and the meeting then terminated.

INSTITUTION NOTES

November, 1945

AWARDS FOR PAPERS PRESENTED DURING 1944-45.

The Council have pleasure in announcing that the following awards have been made for the Session 1944-45:

Institution Medal for the best paper presented by a member to H. Eckersley, Esq., M.I.P.E., for his paper on " Negative Rake Milling."

Institution Medal for the best paper presented by a non-member to R. E. Reason, Esq., A.R.C.S., for his paper on "Surface Finish and its Measurement."

Lord Austin Prize 1944:

The winners of the Lord Austin Prize Essay are: A. B. Dear, Esq., Grad.I.P.E., for his Essay on "Tooling-Up and Equipment for New Contracts " and W. Johnson, Esq., Grad.I.P.E., for his Essay on "An Ideal Training for Apprentices."

November Meetings.

2nd Lincoln Sub-Section. A lecture will be given by R. H. Pinder, Esq., on "Sheet Metal Work," at Lincoln Technical College, at 6-30 p.m.

3rd Yorkshire Graduate Section. A lecture will be given by F. A. Field, Esq., on " The Use and Application of Portable Electric Hand Power Tools," at the Great Northern Hotel, Bradford, at 2-30 p.m.

5th Coventry Graduate Section. "Any Questions Evening," at the Technical College, Coventry, Room A5, at 6-45 p.m.

5th Yorkshire Section. A lecture will be given by T. G. Rose, M.I.P.E., M.I.Mech.E., F.I.I.A., on " How Money moves in Business," at the Lecture Hall, City Museum, Leeds, at 7-00 p.m.

8th Leicester Section. A lecture will be given by E. Hunter, Esq., on " Cast Iron and the Machinist," at the Leicester College of Technology, at 7-00 p.m.

8th South Wales and Monmouthshire Section. A lecture will be given by Dr. W. Wilson on " Electronics in the Service of the Engineer," at the South Wales Institute of Engineers, Park Place, Cardiff, at 6-30 p.m.

November Meetings.—*cont.*

13th Manchester Graduate Section. A lecture on " Press Tools " will be given by Messrs. W. A. Bull, Stringleman and Douglass (Mr. Bull will be dealing with the scope of the subject, Mr. Stringleman with design, Mr. Douglass with manufacture) at the College of Technology, Manchester, at 7-15 p.m.

13th North-Eastern Graduate Section. Film Evening at the Newcastle and Gateshead Gas Co's. Demonstration Theatre, St. John St., Newcastle-on-Tyne, at 6-30 p.m.

13th Birmingham Graduate Section. Film Show presented by the Ministry of Information. The programme covers various aspects of War Production, including Aircraft, Guns, Machine Tools, The Bailey Bridge and Mulberry Harbour, at the James Watt Memorial Hall, Gt. Charles Street, at 7-00 p.m.

13th Luton and District Section. Film Show at The Small Assembly Room, Town Hall, Luton, at 7-00 p.m.

14th Preston Section. A lecture will be given by V. W. Chandon, Int.A.M.I.P.E,.on " Chemical Methods Applied to Production Engineering," at the Canteen of Messrs. Clayton, Goodfellow and Co., Ltd., Atlas Iron Works, Blackburn, at 7-15 p.m.

14th London Section. A Lecture will be given by L. G. Earle, B.Sc., A.R.S.M., on "A Brief Study of Soft Soldering, including a Review of Recent Researches," at the Institution of Mechanical Engineers, Lecture Hall, Storey's Gate, St. James' Park, S.W.1, at 6-30 p.m.

15th Glasgow Section. A lecture will be given by A. L. Hipwell, Esq., on " Negative Rake Turning and Milling," at the Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2, at 7-15 p.m.

16th Manchester Section. A lecture will be given by W. Puckey, M.I.P.E., on " Managerial Aspects of Full Employment," at the Mechanics Institute, Crewe, at 7-15 p.m.

16th Western Section. A lecture will be given by R. E. Rowland, M.I.E.E., on " Infra-Red Lamp Heat for Paint Drying," at the Grand Hotel, Broad Street, Bristol, 1, at 6-45 p.m.

16th Coventry Section. A lecture will be given by E. C. Dickinson, M.Met., on " Recent Developments in Foundry Practice," at the Coventry Technical College, Room A5, at 6-45 p.m.

November Meetings.—*cont.*

16th Eastern Counties Section. A lecture will be given by R. E. Dunnett, M.I.P.E., on "Impressions of the U.S.A. from a Recent Visit," at the Lecture Hall, Electric House, Ipswich, at 7-15 p.m.

17th Nottingham Section. A lecture will be given by E. W. Hancock, M.B.E., M.I.P.E., on "Time Factor in Industry," at the Demonstration Theatre, The City Gas Showrooms, Lower Parliament St., Nottingham, at 2-30 p.m.

17th Manchester Section. A lecture will be given by W. Puckey, M.I.P.E., on "Managerial Aspects of Full Employment," Joint Meeting with the Institute of Industrial Administration, The University, Brownlow Hill, Liverpool, at 2-30 p.m.

19th Coventry Graduate Section. A lecture will be given by J. H. Hobbs, Esq., on "Fine Measurement," at the Gas Showrooms, Rugby, at 7-00 p.m.

19th Derby Sub-Section. A lecture will be given by L. S. Delapena, Esq., on "Machine Tools," at the School of Art, Green Lane, Derby, at 6-30 p.m.

19th Halifax Section. A lecture will be given by C. A. Gladman, Esq., on "Engineering Drawings in Relation to Production and Inspection," at the Technical College, Huddersfield, at 7-00 p.m.

21st Manchester Section. A lecture will be given by Dr. D. F. Galloway, B.Sc., Director of Research I.P.E., on "Machine Tool Research and Development," at the College of Technology, Manchester, at 7-15 p.m.

21st Sheffield Section. A lecture will be given by Dr. H. A. Fells, Ph.D., on "Gas Furnaces and Industrial Heating," at the Royal Victoria Hotel, Sheffield, at 6-30 p.m.

21st Birmingham Section. A lecture will be given by Vincent Everard, Esq., on "Industrial Relationship," at the James Watt Memorial Hall, at 7-00 p.m.

23rd Yorkshire Graduate Section. Visit to Dean Smith & Grace, Ltd., Keighley, Lathe Manufacturers, at 2-30 p.m.

24th Manchester Section. A lecture will be given by A. G. Doughty, Esq., on "Use of Disabled Personnel in Industry," at Liverpool University, Liverpool, at 2-30 p.m.

November Meetings.—*cont.*

24th Shrewsbury Sub-Section. A lecture will be given by E. W. Hancock, M.B.E., M.I.P.E., on "Jig and Fixture Design," at Walker Technical College, Oakengates, at 3-00 p.m.

27th North-Eastern Section. A lecture will be given by W. Shield, Esq., on "The Cost Accountant's Point of View in Relation to the Production Engineer," at the Neville Hall Mining Institution, Newcastle-on-Tyne, 1, at 6-15 p.m.

30th Lincoln Sub-Section. Joint meeting with The Engineering Society, T. G. Tanner, B.Sc., will lecture on "High Frequency Induction Heating," at Lincoln Technical College, at 6-30 p.m.

December Meetings.

3rd Coventry Graduate Section. Joint Meeting with the Graduate Section of Inst. of Mechanical Engineers, Inst. of Automobile Engineers and Royal Aeronautical Society. Full details to be announced later.

3rd Yorkshire Section. A lecture will be given by A. McLeod, M.I.P.E., on "The Technical Press as an Aid to the Production Engineer," at the Hotel Metropole, Leeds, at 7-00 p.m.

6th Glasgow Section. Informal discussion on "Machining Problems," at the Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2, at 7-15 p.m. Problems will be tabled by Messrs. W. Buchanan, J. McFarlane and I. M. Lyon.

7th Western Section. Annual Dinner, Grand Hotel, Bristol, 1. Full details to be announced later.

7th Leicester Section. Joint meeting with the Leicester Association of Engineers. R. M. Evans, Esq., will lecture on "Making a Typewriter," illustrated by lantern slides, at the Leicester College of Technology, at 7-00 p.m.

8th Manchester Graduate Section. Visit to Metropolitan Vickers Co. Works, Trafford Park, Manchester.

8th North-Eastern Section. Social Evening, Neville Hall Mining Institution, Newcastle-on-Tyne.

8th North-Eastern Graduate Section. Works Visit to Messrs. Bushing Co., Ltd., Team Valley Trading Estate, Gateshead.

December Meetings.—*cont.*

11th Luton and District Section. A lecture will be given by H. Fairbairn, Esq., on "Die Casting," at The Small Assembly Room, Town Hall, Luton, at 7-00 p.m.

12th Preston Section. A lecture will be given by V. W. Pilkington. Esq., on "Impressions in America," at the Municipal Technical College, Manchester Rd., Bolton, at 7-15 p.m.

12th Wolverhampton Section. A lecture will be given by J. H. Paterson, D.Sc., on "Replacement of Castings by Welded Fabrication," at the Wolverhampton and Staffordshire Technical College, at 6-30 p.m.

13th Leicester Section. A lecture will be given by F. J. Everest, Esq., on "Developments in Gear Cutting and Finishing Processes," at the Leicester College of Technology, at 7-00 p.m. This lecture will be illustrated by lantern slides.

13th South Wales and Monmouthshire Section. A lecture will be given by A. E. Walsh, M.B.E., A.M.I.I.A., on "Personnel Management, Industrial Psychology, their Place in Post-War Industrial Economy," at the South Wales Institute of Engineers, Park Place, Cardiff, at 6-30 p.m.

13th London Section. A lecture will be given by A. Craig McDonald, Esq., on "Some Modern Methods of Heat Treatment," at the Institution of Mechanical Engineers, Lecture Hall, Storey's Gate, St. James' Park, S.W.1, at 6-30 p.m.

15th Yorkshire Graduate Section. A lecture will be given by R. W. Whittle, M.I.P.E., M.I.Loco.E., A.M.I.Mech.E., on "Rehabilitation into Industry," at the Great Northern Hotel, Leeds, at 2-30 p.m.

15th Shrewsbury Sub-Section. A lecture will be given by A. W. Wallbank, Esq., on "Protective Metal Finishes," at Shrewsbury Technical College, at 3-00 p.m.

17th Derby Sub-Section. A lecture will be given by T. B. Maddison, A.M.I.P.E., on "Production Methods in Railway Workshops" at the School of Art, Green Lane, Derby, at 6-30 p.m.

17th Halifax Section. A lecture will be given by Dr. D. F. Galloway, B.Sc., Director of Research, I.P.E., on "Technical Design on Machine Tools," at the Technical College, Halifax, at 7-00 p.m.

December Meetings.—*cont.*

19th Sheffield Section. A lecture will be given by W. Neville, Esq., on "Shot Peening," at The Royal Victoria Station Hotel, Sheffield, at 6-30 p.m.

19th Birmingham Section. A lecture will be given by A. J. Nicol, Esq., on "Personnel Management as a Service to Production," at the James Watt Memorial Hall, at 7-00 p.m.

20th Glasgow Section. A lecture will be given by R. B. C. Douglas, M.B.E., on "The Training and Employment of the Disabled," at the Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2, at 7-15 p.m.

21st Lincoln Sub-Section. A lecture on "Manufacture of Tractors and Harvesters," at Lincoln Technical College, at 6-30 p.m. Details to follow.

21st Eastern Counties Section. A lecture will be given by R. K. Mawson, Esq., Ministry of Labour, on "Accident Prevention," with special reference to Engineering Machinery, at the Lecture Hall, Electric House, Ipswich, at 7-15 p.m.

November Committee Meetings.

2nd The Finance and General Purposes Committee, at 2-30 p.m., at Institution Headquarters.

27th The Education Committee, at 10-30 a.m., at the Imperial Hotel, Birmingham.

27th The Membership Committee, at 12-30 p.m., at the Imperial Hotel, Birmingham.

The Technical and Publications Committee meet every Wednesday at 5-30 p.m. at Institution Headquarters.

The Research Committee meet once a month at Loughborough College, Loughborough, Leics.

Note.—It is not possible to give details of the Research Committee meetings in the current issue, but it is hoped subsequently to fix a standing date for this.

Council Meeting.

The next meeting of the Council will be held on Friday, 14th December, 1945, at 11 a.m. at the Institution of Civil Engineers, Great George St., S.W.1.

BIRMINGHAM SECTION. Mr. F. C. White, M.I.P.E., so widely known in the Institution through his work as Hon. Secretary to the Birmingham Section, has succeeded Mr. J. L. Munn, M.I.P.E., as Section President.

Mr. A. J. Mansell, A.M.I.P.E., has been elected Hon. Section Secretary.

SHREWSBURY SUB-SECTION. Mr. Bernard Thomas, of Midland Heat Treatments, Ltd., gave a most interesting and informative lecture on "The Theory of Ferrous Heat Treatment," at the Shrewsbury Technical College on 8th September, 1945, which was greatly appreciated by the members and visitors present. The lecture was followed by a discussion. Letters of thanks have been sent to Mr. Thomas and to Mr. A. Moore, Principal of Shrewsbury Technical College.

Personal.

Mr. C. Halse, M.I.P.E., one of the Founder Committee Members of the South Wales and Monmouthshire Section, who is at present engaged as Assistant Superintendent of the Royal Ordnance Factory, Llanishen, Nr. Cardiff, will shortly take up a position as Technical General Manager with Messrs Howards of Sunbury-on-Thames. Mr. Halse has performed considerable service for the Section since its inception. He leaves with the best wishes of all the section members.

Obituary.

We deeply regret to record the death of the following members :—
Alderman H. G. Williams, M.I.P.E., Western Section. Mayor of Gloucester at the time of his death.
E. A. Molesworth, M.I.P.E., Sydney, N.S.W.
G. L. Litchfield, A.M.I.P.E., Nottingham Section.

THE BRITISH PRODUCTION ENGINEERING RESEARCH ASSOCIATION.

Applications are invited for the appointment of a Director-General of the above Association which has been formed to conduct research on a national scale in production engineering.

The Director-General will be responsible for implementing the policy of the Association Council. He should have an adequate knowledge of engineering in addition to the necessary commercial qualifications. Corporate membership of one of the major professional institutions would be an advantage.

His responsibilities will include in particular administration, organisation, and the control of the finances of the association ; and he will represent the Association in contacts with Industry and Government Departments.

The detailed research work will be conducted by the Director of Research.

A salary is envisaged in the order of £1,500 to £2,000 a year, according to qualifications.

Applications, which will be treated in strict confidence, and must be received within a month of the date of this announcement, should be sent in the first instance to :—

THE BRITISH PRODUCTION ENGINEERING RESEARCH ASSOCIATION,
Box, Res. 207,
c/o Standbrook House, Old Bond Street, W.1.

Important.

In order that the Journal can be despatched on time, copy must reach the Head Office of the Institution by not later than 40 days prior to the date of issue, which will be the first of each month.

Books Received.

Centreless Grinding. A Handbook for Beginners and Experts. Published by Arthur Scrivener, Ltd., Birmingham. (Can be had on application from the publishers free of charge.)

Capillary Fittings and Compression Fittings of Copper or Copper Alloy, for use with Light Gauge Copper Tube. Published by the British Standards Institution.

Report for 1944–45—A Survey of the Work of the Zinc Alloy Die Casters Association and the Zinc Pigment Development Association.

APPLICATIONS FOR MEMBERSHIP AND TRANSFER RATIFIED AT THE SEPTEMBER COUNCIL MEETING.

* *Applicants elected by the Council.*

As Members: A. D. Abbott, H. M. Brack, G. W. Deakin, S. L. Grove, E. Kilayin, S. W. Nixon, F. J. Tector.

As Associate Members: H. Adcock, G. Bamford, J. T. Barnsley, J. S. Beattie, A. Beecham, S. Bell, C. H. Bingham, C. S. Blomfield, A. Campbell, A. Clough, H. M. Court, A. Dalby, R. R. Dunk, N. C. Earll, J. Farran, J. C. Firth, A. F. Frost, D. F. Galloway, J. S. S. Gardner, P. G. Garside, *J. C. Goldie, W. E. Griffin, F. J. Gunn, H. Hale, H. Handforth, G. C. H. Harnden, W. G. Heath, A. A. Hill, E. B. Hiorns W. Holmes, C. W. Howells, F. Hughson, D. M. Irving, R. F. W. Keay, J. Low, *J. C. MacColl, K. V. Mason, A. W. Millward, T. S. G. Neville, G. C. Newman, N. T. Radcliffe, *F. Robinson, H. P. Sanderson, E. J. Skinner, C. H. Stevens, G. T. Stevenson, A. E. Terrington, L. Tinsley, I. J. Webb, H. E. Wheeler, W. W. Wright, A. Yates.

As Associates: R. Hickling, S. L. Smart, A. J. Smith.

As Intermediate Associate Members: A. C. Badger, H. Beaumont, A. L. Beech, R. E. Bird, J. Booth, N. J. Brader, *W. L. Brenchley, R. G. Broome, W. L. Bruchhauser, *T. E. Burr, R. Button, M. Clegg, W. J. Cowell, S. Cundill, H. Cunnington, M. L. Curtis, T. Davenport, W. B. Egerton, S. Elliott, F. Forrest, J. H. Forrington, T. H. Fox, L. P. Garratt, R. J. Harris, J. A. Hartley, R. Hayward, H. G. Holman, L. E. Holton, H. S. Hughes, D. A. Jones, D. M. Kott, C. Lacey, J. A. Land, E. Letts, J. H. Longhurst, J. W. McGowan, A. D. McPhie, J. Martin, L. Martin, E. G. Merrington, E. W. Moon, J. R. Nortier, J. Palmer, I. Parkes, G. H. Parlor, D. R. P. Poole, A. D. Prakel, C. E. Ravenall, H. H. Reid, R. Rees, S. Richardson, J. C. Routledge, R. V. Schulz, J. C. Sharman, *G. E. O. Taylor, I. Thomas, W. C. Thurston, W. L. Voyle, *H. H. Ward, *J. Worth, E. O. Wright, F. Yeomans.

As Graduates: G. C. Davey, G. H. Gamble, N. T. Harper, A. Herbert, N. Jackson, R. H. Jeffs, G. Lee, G. G. Marshall, L. M. Organ, K. S. Ramaswamy, *K. C. Rooke, D. A. Smith, J. A. Taylor, E. R. Unitt, J. W. Walker, C. W. Whitehead, R. L. Wortley.

As Students: F. Ainley, G. E. Annan, R. Bailey, T. H. Beard, G. Brooke, A. E. R. Chambers, H. Chorley, S. Clare, W. Colley, R. H. Collins, J. P. Cross, P. M. Dean, H. J. Faull, A. Firth, K. W. Fisher, A. Garner, C. L. Griffiths, A. R. Haycock, *H. Hodgson, J. C. Holt, E. H. Lane, J. P. Lendrum, E. H. G. Littlejohn, G. V. Marston, G. B. Millard, A. J. Mee, J. Mills, E. H. Mountford, D. Needham, C. G. Pfaff, P. B. Rogers, A. G. Saunders, A. T. H. Selby, W. Simpson, J. Spiegel, E. Stephenson, G. Stockdale, K. Tasker, R. J. Taylor, G. P. Tomlinson, F. Tully, N. Varley, D. Walker, R. L. Webb, A. White, J. G. Wood, D. Woolridge, D. W. Wright, A. C. Wyatt.

As Affiliated Firms:	**New Affiliate Representative:**
J. E. Baty & Co. Ltd.	W. A. D. Dawson.
British Mechanical Products, Ltd. ...	D. H. Paton.

TRANSFERS.

From Associate Member to Full Member : G. Chadwick, H. A. Colton, G. W. Corkindale, R. F. Elliott, W. Fletcher, W. V. Hodgson, P. S. Taylor, W. Winters.

From Intermediate Associate Member to Associate Member : E. Andrews, A. H. F. Bowness, N. Fitton.

From Graduate to Associate Member : A. R. Aspinall, B. A. I [illegible]ins W. G. A. Inglis, W. E. Jeffries, D. H. Morgan, G. R. B. Parker.

From Graduate to Intermediate Associate Member : R. L. Aston, K. C. Buteux, H. G. Dagger, C. F. Gazard, H. E. Inckle, H. Lister, R. W. Marston, P. R. Pelly, R. E. W. Smith, *O. Stanley, A. H. Webster, T. Zweigbergk.

From Student to Graduate : G. W. Brown, R. Cooper, T. W. Funston, P. G. R. Haines, D. M. Hallam, D. E. H. Johnson, D. Lacey, L. K. Lord, D. J. Taysom.

Research Department:
Production Engineering Abstracts

(Prepared by the Research Department.)

NOTE.—*The Addresses of the publications referred to in these Abstracts may be obtained on application to the Research Department, Loughborough College, Loughborough. Readers applying for information regarding any abstract should give full particulars printed at the head of that abstract including the name and date of the periodical.*

HEAT TREATMENT.

Fuel-Fired Techniques and Their Possibilities, by Frederic O. Hess. (*Mechanical Engineering* (*U.S.A.*), *July*, 1945, *Vol.* 67, *No.* 7, *p.* 422, 6 *figs.*)

High-speed heating is defined as a heating rate at which the heat-absorption capacity of the workpiece is neared by approaching destruction of its surface, while the underlying portions are considerably below the temperature range of destruction. The heating of ferrous and non-ferrous metals is discussed, and it is concluded that: (*a*) the gas technique of high-speed heating is in the pioneer phase. (*b*) Research data will eventually provide proper correlation between heat source, temperature and conductivity. (*c*) We require a new analysis of heating, metallurigcal, and process requirements to find the proper field of usefulness for this technique. (*d*) Conductivity can enter into the selection of a steel for a certain product, in the same manner as carbon content, alloy additions, and cost.

Time-Temperature Relationships in Workpieces, by Victor Paschkis. (*Mechanical Engineering* (*U.S.A.*), *July*, 1945, *Vol.* 67, *No.* 7, *p.* 445, 6 *figs.*)

A discussion of fundamental factors.

High Frequency Induction Heating, by Wesley M. Roberds. (*Mechanical Engineering* (*U.S.A.*), *July*, 1945, *Vol.* 67, *No.* 7, *p.* 448, 4 *figs.*)

The purpose of this paper is to show how induction heating compares with other more conventional methods. Induction heating produces the highest possible power concentrations on certain classes of work and lends itself to a nicety of control which far exceeds that of any other heating method. The chief limiting factors in induction heating are the shape of the work and the electrical and magnetic properties of its material. The work should be symmetrical. Induction heating is best for jobs where non-uniformity is desired, *i.e.*, where high temperature gradients are to be established. The evaluation of intensity and control factors are discussed and their implications indicated. Hardening thin shells is taken as an example. It is concluded that the experimental side of induction heating is considerably ahead of the theory, due to the extremely laborious calculations involved. The conduction of heat is at astonishing rates with the temperature rates involved. The maximum power concentrations at present are 100 kW per sq. in.

Continuous Heat-treatment of Bars by High-frequency Induction. (*Machinery*, 13*th September*, 1945, *Vol.* 67, *No.* 1718, *p.* 281, 5 *figs.*)

The bar is fed continuously through an inductor coil, and temperature adjustment is effected by carefully controlling the speed of travel of the work, and the power input. Speeds from 20 to 60 inches per minute are obtained. Machines for continuous heat-treatment and the case-hardening of tank-track pins are described.

BELTS, ROPES.

V-Flat Drives, by F. Grossman. (*Power Transmission*, 15*th September*, 1945, *Vol.* 14, *No.* 164, *p.* 800.)

A method of determining the power transmitted by V-flat drives is developed. Tables of correction factors are given to assist calculation.

The Prevention of Faulty Splices, by H. Stuart Jude. (*Power Transmission*, 15*th September*, 1945, *Vol.* 14, *No.* 164, *p.* 783, 5 *figs.*)

General notes on splicing and likely troubles.

COMBUSTION, FURNACES.

Heat Balance of Industrial Furnaces, by C. S. Darling. (*Mechanical World*, 31*st August*, 1945, *Vol.* 118, *No.* 3061, *p.* 235, 5 *figs.*)

The performance of a normal forge furnace is studied to show how the various aspects of heat distribution can be made to give a true bill for the process of heat recovery. Losses due to radiation from openings, exhaust gas, etc., are evaluated and represented by Sankey heat flow diagrams. It is concluded that improvement of furnace efficiency can be secured by : reduction of wall losses (radiation, conduction, storage, etc., and reduction of exhaust gas loss.) Heat recuperated from the exhaust gases by air preheat represents high heat economy.

COOLANTS, LUBRICANTS.

Selection of Cutting Fluids, by James R. Chambers. (*Machinery* (*New York*), *June*, 1945.)

After dealing briefly with the purposes served by cutting fluids, the author discusses soluble oils, base oils, mineral oils, and fluids for steel, cast irons, brass, aluminium alloys and magnesium alloys.
(*Communicated by Machine Shop Magazine.*)

Cutting Oils, by D. L. Samuel. (*Engineering Materials*, *August*, 1945, *Vol. III*, *No.* 7, *p.* 149.)

The main functions of cutting oils are (1) cooling, (2) lubricating, and (3) increasing the life of the tool and improving the finish of the work. The required properties, which depend on the work involved, include good thermal properties, high specific heat, good wetting properties, non-corrosiveness, low viscosity and flash point high enough to eliminate fire risks. Soluble oils have excellent cooling properties, but tool wear may be considerable. Neat cutting oils are used where conditions are severe and life is all important, as in hobbing, gear-cutting and forming processes. Soluble oils have been improved by increased stability and clearer slurries. Neat cutting oils have also been developed by the use of blends of fatty and mineral oils, combined sulphur and chlorinated compounds.

ELECTRICAL ENGINEERING.

Applications of Electronics in Industry, by L. T. Campey. (*The Australasian Engineer*, *7th July*, 1945, *Vol.* 44, *No.* 349, *p.* 44, 21 *figs.*)

Electronics can be defined as that branch of science and technology which relates to the conduction of electricity through gases or in vacuo. The outstanding characteristics of electronic tubes are: (1) amplification of minute electrical signals; (2) rectification of alternating current; (3) operation over a large range of electrical frequencies; (4) rapid and precise operation. Industrial applications have been made to: (1) Power rectification and frequency conversion. (2) Adjustable-speed electronic drive. (3) Resistance welding control. (4) Electronic heating. (5) Temperature control. (6) The electric eye. (7) Inspection, testing and counting. (8) Measurement. (9) Positioning control. (10) Speed matching and voltage control. (11) Electronic timing. (12) Lighting and lighting control. (13) X-rays in industry. (14) Electrostatic precipitation. (15) Carrier current. A comprehensive review of the equipment and its advantages and limitations for all these uses is given.

Fundamentals of the Electronic Valve, by J. R. Cornelius. (*Machinery*, *6th*, *13th September*, 1945, *Vol.* 67, *Nos.* 1717, 1718, *pp.* 259, 289, 18 *figs.*)

Simple electronic theory is discussed and its applications to the diode, photo-electric cells, triodes, tetrodes and pentodes, thyratrons and cathode-ray tubes are fully described.

EMPLOYEES.

Planned Handling of Personnel Problems, by John V. Ellis. (*The Machinist*, *8th September*, 1945, *Vol.* 89, *No.* 22, *p.* 751.)

Planned handling of industrial personnel problems is the basis of "Training Within Industry." Intended primarily for promoting a better understanding of these problems by factory supervisors, it also correlates production planning with all types of labour problems. The value of such a plan is discussed with the aid of actual examples drawn from experience.

FOUNDRY, CASTING.

Iron Casting Runners and Feeding Heads, by T. Waterfall. (*Machinery Lloyd* *1st September*, 1945, *Vol. XVII*, *No.* 18, *p.* 70.)

The causes of bad runners are discussed, and improvements are suggested. Information is given on the effect of area of mould, position of runners, top pouring, the planning of runners, pouring precautions, influence of metal temperature, rate of casting, influence of mass, effects of machining properties, and area of runners.

Flexible Die-Casting Dies for Low Melting Point Alloys, by H. K. Barton. (*Machinery*, *30th August*, 1945, *Vol.* 67, *No.* 1716, *p.* 244, 5 *figs.*)

There has recently been developed a method of die-casting in flexible rubber dies which has already proved itself of exceptional utility for the production of novelties, and may find wider scope. Alloys with melting points up to 600°F. can be cast. Centrifugal casting is used. The manufacture of the dies themselves, and their subsequent use are fully dealt with.

GEARING.

The Effect of Chemical Surface Treatment on the Scuffing of Gears, by H. D. Mansion. (*Power Transmission*, 15*th September*, 1945, *Vol.* 14, *No.* 164,*p.* 774.)

Part I. Phosphate treatments, a caustic soda-sulphur treatment, electrolytic tin plating, anodic deposition of colloidal graphite, and a nitric acid etch treatment were investigated. The treated gears were run in I.A.E. gear testing machines for scuffing tests, running-in tests, and endurance tests. The greatest protection against scuffing was afforded by the deep phosphate treatment, the mean scuffing load being raised to 2·22 times that for untreated gears. The order of the others was: shallow phosphate treatment 1·46, caustic soda-sulphur treatment 1·29, and colloidal graphite treatment 1·21. The tin plating treatment gave no increase. It was decided that it would be most profitable to confine further investigations to the phosphate treatments.

LIGHTING.

Discharge Lamps. (*Mechanical World*, 21*st September*, 1945, *Vol.* 118, *No.* 3064, *p.* 321, 4 *figs.*)

The basic theory is explained and excitation and ionisation voltages are listed. The cold cathode (*e.g.*, neon tube) colour characteristics and length of tube are suitable for decorative purposes only. Metallic vapour lamps include mercury and sodium: the latter has great power of penetrating dust, smoke and fog. Other metals which may be used have high efficiency, but the light is not suitable for most purposes. Gases can be mixed to obtain a blended colour. Hot cathode lamps, used at lower gas pressure and higher current density than the cold cathode tube, are used only where a concentrated beam of high intensity is required. To obtain efficient light of the required colour characteristics the fluorescent discharge lamp has been developed. Ultra-violet rays generated in the lamp are projected on to fluorescent substances, to obtain light of practically any colour required. Suppression of radio interference is necessary. Possible faults are indicated.

MACHINE ELEMENTS.

Selection and Application of Fastening Devices. (*The Machinist*, 8*th September* 1945, *Vol.* 89, *No.* 22, *p.* 757.)

Description of all type of screws, studs, fasteners, etc., and associated equipment.

A New Drawing Office Appliance. (*Aircraft Engineering*, *August*, 1945, *Vol. XVII*, *No.* 198, *p.* 242, 6 *figs.*)

The new machine, known as the Martin Axonograph, is a device for photographically translating a conventional orthographic drawing into a scale representation of one face or dimension of a trimetric projection. The other two dimensions or faces are then filled in by a draughtsman to give a scale trimetric drawing in from one-fifth to one-half the time which would be normally needed. Four new drawing instruments have added considerably in the work. They are: a trimetric scale with its three faces calibrated to correspond with the three axes of the trimetric drawing; an ellipse template; an ellipse underlay; and a trimetric protractor. Diagrams and examples are given.

The Relationship between the Dimensions of Containers, by Kenneth L. Jackson. (*Sheet Metal Industries, September*, 1945, *Vol.* 22, *No.* 221, *p.* 1555, 6 *figs.*)

The object of this work is the determination of the dimensions of certain standard types of metal boxes which will give a required volume with a minimum quantity of plate, using Newton's method of approximation.

Spring Couplings, by R. Waring-Brown. (*Power Transmission*, 15*th September* 1945, *Vol.* 14, *No.* 164. *p.* 768, 6 *figs.*)
Specialized designs are described and illustrated.

MACHINING, MACHINE TOOLS.

Indicated Principles of Post-war Machining, by Carl Himmelright. (*Mechanical Engineering* (*U.S.A.*), *July*, 1945, *Vol.* 67, *No.* 7, *p.* 473.)

Machining practices developed to meet war conditions include: the use of tumbling barrels for burring of aircraft parts to remove sharp edges and corners, and improve suface quality; the production of gear trains practically without backlash with jig bored housings, accurate gear shaved teeth, close-tolerance threading and tooling for close-tolerance work. Cutters for boring, milling and planing have been developed which produce surfaces having such finish that watertight fits could be maintained without the use of gaskets. With the further development of cutting tools, the possibilities of high precision machining in post-war production are greatly increased. Fixtures, cutting tools, and machine tools, should be designed with the realization that high precision makes for high production. The former reliance on the skill of operators should be replaced by proper use of precision machines and tooling.

Machining Laminated Fabrics. (*Production and Engineering Bulletin, August*, 1945, *Vol.* 4, *No.* 32, *p.* 327, 7 *figs.*)

Greatly improved results are now being obtained by using tools tipped with hard metals. Suitable saws, routing cutters and fly cutters have been successfully used at cutting speeds from 1000–7000 f.p.m.

Machining of Ferrous and Non-ferrous Materials, by J. W. Donaldson. *Metal Treatment, Spring*, 1945, *Vol.* 12, *pp.* 4–12.)

Machineability is an important factor in recent metallurgical developments, and this can be controlled within certain limits. The cutting tool materials are discussed in detail: high speed steel, sintered carbide and diamond tools. The improved finish obtainable by diamond tools is stressed, as well as the increased life which compensates for increased costs.
(*Communicated by Industrial Diamond Review.*)

Surface-Speed Chart for Precision Boring, by Bruno Holmstrom. (*The Machinist Reference Book Sheet*, 15*th September*, 1945, *Vol.* 89, *No.* 23, *p.* 819.)

The chart helps to select surface cutting speed for a wide range of S.A.E. steels.

Surface-Finish Chart for Precision Turning and Boring, by Bruno Holmstrom. (*The Machinist Reference Book Sheet*, 15*th September*, 1945, *Vol.* 89, *No.* 23, *p.* 817.)

The chart relates ^{h}rms with tool radius and feed per rev. for non-ferrous materials in general. No differentiation is made for different metals and results can only be approximate.

Friction Sawing, by R. C. Holloway. (*The Machinist*, 15*th September*, 1945, *Vol*. 89, *No*. 23, *p*. 809, 6 *figs*.)

Plate materials, chiefiy SAE 4140, stainless steel and armour plate, are cut at rates of the order of six times faster than bandsawing.

Surface Broaching in an Aircraft Factory. (*Machinery*, 30*th August*, 1945, *Vol*. 67, *No*. 1716, *p*. 225, 10 *figs*.)

Broached surfaces are used in joints for spar-boom members of Vickers aircraft. Details of serrations and teeth on a typical spar boom and joint plate are shown, with the very fine tolerances allowed. The equipment and operations required are described in detail.

Surface Broaching in the Production of Gun Components. (*Machinery*, 20*th September*, 1945, *Vol*. 67, *No*. 1719, *p*. 309, 9 *figs*.)

The introduction of surface broaching has effected material economies. A nickel-chrome hammer-plate, stages in the production of which are shown, requires only 62 instead of 100 min. total machining, bench, and processing time. The broaching of a nickel-chrome-molybdenum ejector is also described.

Precision Bevel Gears Cut Quickly, by Ernest Wildhaber. (*The Machinist*, 15*th September*, *Vol*. 89, *No*. 23, *p*. 802, 9 *figs*.)

The Revacycle process is used for large quantity production of straight-tooth bevel gears up to the size of automotive differential gears. A large disk-type cutter roughs and finishes a tooth space in a single revolution. This process takes only 2½ to 3½ sec. to complete a tooth space of a differential pinion. Ease-off at the tooth ends may be attained at will. The development of the desired cutter shapes is fully described.

Diamond Hones, by F. Whitehead. (*Aircraft Production*, *September*, 1945, *Vol. VII*, *No*. 83, *p*. 442, 4 *figs*.)

Stainless steel cylinder sleeves require a truing operation after nitriding and grinding of the bore to remove chatter marks and produce a perfectly round cylinder. Ordinary silicon carbide honing sticks do not remove the irregularities from the surface layer, which has a Vickers hardness of 509–1,027. Vitrified and metal bonded diamond hones are giving satisfactory service. Special hones for simultaneous honing inside and outside are described. Honing is performed with paraffin and lard lubrication. Usually the honing operation is followed by lapping with a cast iron lap and a mixture of silicon carbide and lard oil.

CHIPLESS MACHINING.

Thread Rolling on Automatics. (*Production and Engineering Bulletin*, *August*, 1945, *Vol*. 4, *No*. 32, *p*. 313, 16 *figs*.)

With thread rolling attachments it is frequently possible to complete a job at one setting in the automatic which would otherwise require one or more subsequent operations. In other instances threads are being formed by rolling which it would be difficult to produce by any other means. They may also be used for straightforward jobs. A selection of examples are given.

Calculating Bend Allowances, by J. B. Clegg. (*Sheet Metal Industries*, *September*, 1945, *Vol*. 22, *No*. 221, *p*. 1575, 4 *figs*.)

For large radii, calculations based on the mean line are usually sufficiently accurate. In bending to a small radius, the strain difference between the metal

on the inside and that on the outside must be taken into account. The author has developed a method of calculating all bend allowances on the basis of observations made on working mild steel.

The Extrusion of 8-inch Diameter Brass Tubing. (*Machinery*, 6*th September*, 1945, *Vol.* 67, *No.* 1717, *p.* 253, 12 *figs.*)

The technique employed in using a 4,000-ton hydraulic press.

MANUFACTURING METHODS.

Abrasives and Grinding Wheel Manufacture. (*Mechanical World*, 31*st August*, 1945, *Vol.* 118, *No.* 3061, *p.* 239.)

A flowsheet shows the schematic layout for manufacture. Explanatory notes are given.

Compound-angle Holes and Surfaces, by N. P. Skinner and K. L. C. Legg. (*Machinery*, 20*th September*, 1945, *Vol.* 67, *No.* 1719, *p.* 323, 18 *figs.*)

Part I. A theoretical treatment is developed which will cover most problems and avoids trial-and-error methods. Set-up methods are also described.

Modern Can-Production Methods. (*The Machinist*, 22*nd September*, 1945, *Vol* 89, *No.* 24, *p.* 821, 4 *figs.*)

Part I. Automatic machines produce up to 300 preserving cans a minute. Cutting, bending, soldering, flanging, flexing, and stamping operations.

Practical Ideas on Tube Bending and the Development of Circles. (*Sheet Metal Industries*, *September*, 1945, *Vol.* 22, *No.* 221, *p.* 1601, 4 *figs.*)

Short description of pipe bending methods.

Aircraft Hydraulic Units, by J. A. Oates. (*Aircraft Production*, *September*, 1945, *Vol. VII*, *No.* 83, *p.* 414.)

Part I. The production of Dowty undercarriages for Lancasters is described. The operations include tube boring and multiple-spindle drilling.

Time Study of Heavy Production Work, by C. D. MacKinnon. (*The Machinist*, 15*th September*, 1945, *Vol.* 89, *No.* 23, *p.* 789, 2 *figs.*)

It is difficult to estimate production times and costs when machining large components, unless they are repetitive and times can be set by observation. The author describes a method for determining them when jobs occur infrequently.

Time Study, by R. Ashton-Lomax. (*Aircraft Production*, *September*, 1945 *Vol. VII*, *No.* 83, *p.* 433, 12 *figs.*)

The aim of the article is to present the principles of time study in such a concise and straightforward manner as to point out to factory managements the simplicity of making time studies and the possibility of these being made by members of their respective engineering staffs after a very short period of study, and serve as a guide to the student observer. The average rate-fixer can master the rudiments in a week and after a little practice can apply his knowledge with confidence. Sample studies given cover: A simple press operation ; a drilling

operation ; a " synthetic " study or chart ; a machining process ; study of a " variable " ; a stage in the assembly of a camera : a stage in the assembly of an aircraft wing. General points raised are : the utmost importance of complete honesty, the selection of personnel to carry out the work, and the instructions to the observer.

MATERIALS.

Diamond Dust—A Review of Recent Literature. (*Industrial Diamond Review, August*, 1945, *Vol.* 5, *No.* 57, *p.* 169.)

Data from recent publications are given on dust for bonded wheels, machining of sintered carbides, and the machining of diamond itself, the shaping of synthetic sapphire jewel bearings, and for certain applications in lens making. The information covers production methods, diamond dies and diamond tipped tools, machining synthetic sapphire and quartz, grinding sintered carbide tools and dies, and preparing laps.

MEASURING METHODS, INSPECTION.

Electron Microscopy. (*Aircraft Production*, *September*, 1945, *Vol. VII*, *No.* 83, *p.* 451, 5 *figs.*)

The design of the electron microscope is based on the fact that it is possible to make highly magnified images with electron optical systems by combining two or more electronic lenses, with no limit imposed by the wavelength of visible light. The present instruments enable magnification of more than 50 times that of best light microscopes, *i.e.*, 100,000. The R.C.A. microscope and the G-E simplified type are described.

PLASTICS.

Four Basic Types of Moulds Used on Thermosetting Plastics, by D. M. Buchanan. (*The Machinist*, 1*st September*, 1945, *Vol.* 89, *No.* 21, *p.* 725, 12 *figs.*)

The different types of moulds, the moulding processes, and the considerations in their choice are discussed.

Transfer Moulding, by D. M. Buchanan. (*The Machinist*, 15*th September*, 1945, *Vol.* 89, *No.* 23, *p.* 799, 8 *figs.*)

Moulding by the transfer method permits the application of the thermosetting materials to many constructions that cannot be moulded by compression methods, such as exceptionally complicated forms that are impossible to hold to close tolerances by other methods. Large numbers of inserts of intricate shapes can be accurately positioned and moulded.

Plastics in the Manufacture of Motor Commutators. (*Machinery*, 13*th September*, 1945, *Vol.* 67, *No.* 1718, *p.* 285, 4 *figs.*)

Plastic materials are used not only for insulating the copper segments from each other when the commutators are being assembled, but also to mould the copper segments into a circle after assembly. The properties of plastics suitable for commutator moulding are specified. An assembling fixture is used to prepare the segments for the moulding operation. This fixture, the moulding die, and the moulding operation are described.

Survey of Laminated Plastics, by P. D. Ritchie and I. W. A. Kirkwood (*Engineering Materials, August*, 1945, *Vol. III, No.* 7, *p.* 141.)

This survey of the present position and the outlook for the future briefly reviews : laminated sheet with inorganic fibrous layers, transparent laminates, multi-coloured laminates, wire-reinforced laminates, and laminates with " track resisting " surfaces. Recent advances in the Silicone resin group are described in greater detail.

Plastic Mouldings and Zinc Alloy Die Castings. (*Prepared by The Zinc Alloy Die Casters Association.*)

These notes have been compiled in the light of present knowledge to show the fundamental advantages and disadvantages of plastic mouldings as they exist to-day, in comparison with zinc alloy die castings. Plastic mouldings with die cast zinc alloy inserts are also described. It is concluded that plastic mouldings are likely to have little effect on engineering applications of die castings where high mechanical properties and dimensional stability are required. For ornamental uses, however, they are likely to meet serious and increasing competition from plastic mouldings. Use of the two materials in combination appears to hold out many interesting possibilities.

RESEARCH.

Radial Rake Angles in Face Milling, by J. B. Armitage and A. O. Schmidt. (*Mechanical Engineering* (*U.S.A.*), *July and August*, 1945, *Vol.* 67, *Nos.* 7 *and* 8, *p.* 453 *and* 507, 29 *figs.*)

Part II. High cutting speeds, from 1,000 to 3,500 surface ft. per min., have been frequently recommended for steel milling operations, but from this and other investigations it is considered that they are not to be generally recommended for carbide-steel milling. Primary factors in determining cutting speeds are the power available at the spindle, type of cut and surface finish required. The use of heavy feeds per tooth, from 0·010 to 0·015 in., at cutting speeds from 350 to 750 f.p.m., are recommended. Factors affecting tool life include : mechanical failure (breaking, cracking, checking, or fracture), friction, and the heat generated. Tests were performed on a 50 h.p. vertical milling machine with a fly cutter 10 in. in diam., having a solid-carbide blade. The object was to study the effect of the friction and the accumulated concentrated heat around the cutting edge. Negative radial and axial rake angles and a 15-deg. peripheral cutting-edge angle were used. ·010 in. feed per tooth and ·150 in. depth of cut were used with cutting speeds from 130 to 3280 f.p.m. The influence of cutting speed on chip formation and wear is illustrated by photographs. The conclusions were (1) There is an upper and lower limit of cutting speed in steel-milling practice at which cemented carbides will give best results. (2) A cutting speed of approximately 500 surface ft. per min. will result in good chip formation. (3) As the cutting speed is increased, wear at the cutting edge and consequently changes in tool angles become more pronounced. (4) A fine chip of 0·0005 in. thickness will cause more abrasive wear at the cutting edge than a coarse chip of 0·010 in. per tooth.

Part III. The object of this series of tests was to investigate the effect of cutting speed on tool life and chip formation of a combined positive and negative-radial-rake-angle cutter. The fly cutter had a 15-deg. positive secondary radial rake angle and a 10-deg. negative primary radial rake angle. The conclusions were : (1) Wear on the cutting edge increases with an increase in cutting speed, but the cutter with double radial rake angles reveals better wearing qualities than a negative-radial-rake-angle cutter operating under similar conditions. (2) Any

reduction in wear at the cutting edge increases tool life between regrinds. (3) Less carbide is removed in the sharpening operation on combined-angle cutters. (4) Application of double radial rake angles in cutter design will reduce power consumption at the cutting edge with a resultant increase in machine efficiency, and will lessen forces acting on machine and workpiece.

SHOP ADMINISTRATION AND MANAGEMENT.

The Technique of Process Planning, by D. Tiranti. (*Mechanical World*, 21*st September*, 1945, *Vol.* 118, *No.* 3064, *p.* 313, 2 *figs.*)

An actual case drawn from optical glass shop practice is taken as an example and the planning for the manufacture of one part is given in full.

The Technique of Production Planning, by D. Tiranti. (*Machine Shop Magazine*, *August*, 1945, *Vol.* 6, *No.* 8, *p.* 56. 5 *figs.*)

Part 2—deals with use of batch size, number of batches, alteration of batch size, economic batch, assembly call-up, unit breakdown, material, call-up, schedules, and part list.

SMALL TOOLS.

The Sub-zero Treatment of Hardened Steels, by J. D. Jevons. (*Engineering Materials*, *August*, 1945, *Vol. III*, *No.* 7, *p.* 139.)

The changes induced by cooling hardened steels to sub-zero temperatures have been known for many years, but refrigerating equipment for commercial use has only recently become available. The benefits to be derived from the sub-zero treatment are greatest with highly alloyed tool steels, such as high-speed steel. The benefits derived from proper sub-zero treatment are: (1) An increase in hardness. (2) An increase in toughness. (3) An increase in the life of cutting tools, though the claims for increases of several hundred per cent. should be regarded as exceptional rather than commonplace, and (4) the giving of almost complete dimensional stability to parts such as hardened steel gauges. The temperature generally used is —80°C. Treatment must be given as soon as possible after the hardening operation, since ageing at room temperature tends to make subsequent breakdown of austerite difficult. It is certain that sub-zero treatment will be of considerable benefit, but further knowledge is still needed on the practical details of how the desired changes can be introduced with the least danger of cracking and in the most economical way under industrial conditions.

Tool Steel Developments, by Bernard Thomas. (*Engineering Materials*, *August*, 1945, *Vol. III*, *No.* 7, *p.* 157.)

Practical drawbacks attached to the use of crucible steel have resulted in the development of alloy steels, modern hot die steels, cold die steels, steels for press tools, shear blades, form tools, pneumatic tools and chisels. Creep-resisting steels, spring steels, high-speed and substitute high-speed steels have also been developed. Suitable compositions and heat treatments for different applications of these steels are given.

Cutting with Carbides. (*Machine-Tool Review*, *July–August*, 1945, *Vol.* 33, *No.* 198, *p.* 78, 12 *figs.*)

The ideal chip for maximum performance is a long continuous flat ribbon on which the minimum of work has been expended, but such a chip is most difficult

and dangerous to handle and must be subjected to control by means such as chip breakers. Step breakers of suitable dimensions, the Chipstream tool and Boxtool, and a Box-type chipbreaker are described and practical points in their use are discussed. Some slight benefit in carbide tool performance can be obtained by the use of coolants, but in general these gains are more than offset by the disadvantages resulting from the heavy spray produced by the rapidly rotating work or cutter and by the flying chips, the cracking of tips and a serious risk of fire if oil is used as a coolant for negative rake tools.

Diamond and Sintered Carbide Wire-Drawing Dies. Their Maintenance and Use. (*Industrial Diamond Review, July*, 1945, *Vol.* 5, *No.* 56, *p.* 145.)

Care must be taken to obtain the correct size, shape and carat weight of die. Dies should be kept under constant supervision, and should be scrapped when rectification becomes too costly, especially as they may give very poor subsequent service. The use of coarse diamond powder in re-boring must always be followed by a finer grade. The shape of the needle determines the shape of the die, and a grinding machine which will repeat the angles is of great assistance. Centring and chucking must always be done carefully or much unecessary work will ensue, with wastage of the dies. Time spent in hand polishing diamond dies is wasted, and machines should be used. Care results in economy of diamond paste. Service data for drilling and polishing are given with comments on different types of machine. The vital part that correct lubrication plays, used in wire-drawing, and its effect on die performance and life, is still not sufficiently realised.

Machining Brass ; Turning, Milling and Boring with Diamond Tools, by W. Stern. (*Metal Industry*, 30*th March*, 1945, *Vol.* 66, *pp.* 194–196, *reprint.*)

Optical and astronomical instrument makers were probably the first users of shaped diamond tools. Tabulated service data and examples for turning thin brass tubes, machining armature parts on special lathe.

(*Communicated by Industrial Diamond Review.*)

Tool Data for Precision Boring, Parts I and II. (*The Machinist Reference Book Sheet*, 8*th September*, 1945, *Vol.* 89, *No.* 22, *p.* 769, 3 *figs.*)

Part I. A chart of neutral angles gives the actual back rake angle that must be ground on the tool in order to obtain an effective rake of zero degrees when the tool is set at a special height above centre in a hole of a given size. Bore clearance angles are given for different materials.

Part II. The function termed blending angle is explained and tables of values are given.

Short-run Press Tools, by P. Wise. (*Machinery*, 6*th September*, 1945, *Vol.* 67, *No.* 1717, *p.* 268, 3 *figs.*)

There is a great reluctance to produce tools which deviate from the conventional, either in design or in their mode of operation. The author criticizes the attitude of regarding a press tool as a piece of auxillary machinery and not as something which wears out, and should be designed in relation to its expected life. The design of dies, strippers, bottom bolsters and punches, and die construction and assembly, are critically discussed in this light.

INDEX TO ADVERTISEMENTS

As a war-time measure the advertisement section of this Journal is now published in two editions, A *and* B. *Advertisers' announcements only appear in one edition each month, advertisements in edition* A *alternating with those in edition* B *the following month. This Index gives the page number and edition in which the advertisements appear for the current month.*

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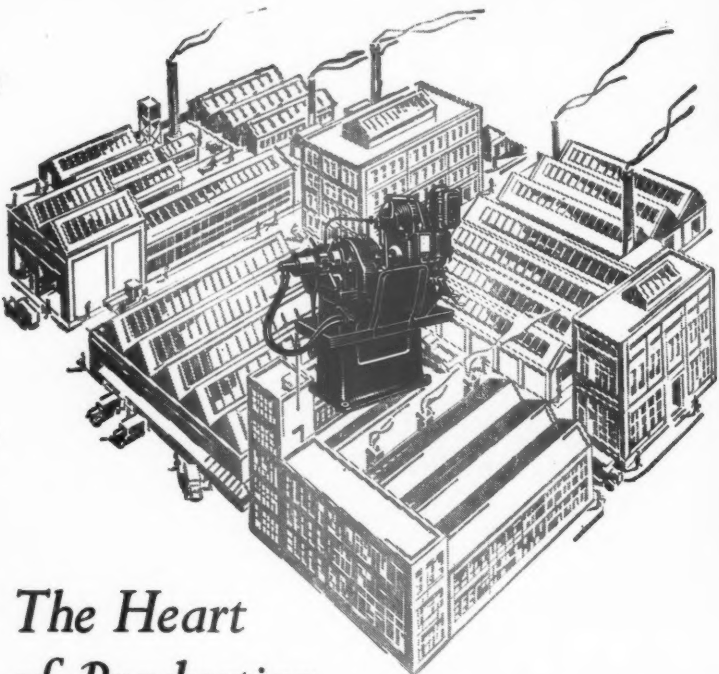

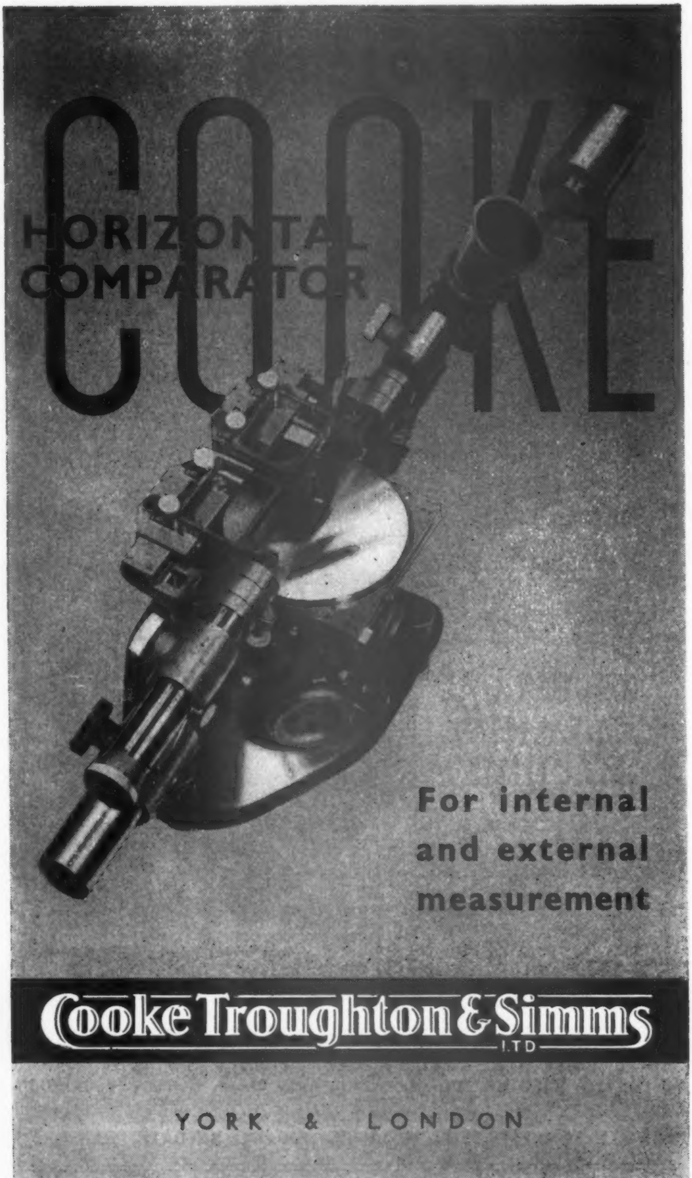
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"He's a what?"

asked the Young Apprentice.

"A Craftsman" repeated the Oldest Employee.

"*Oh!" said the Y.A. "I thought you said something else.*"

"It comes to the same thing. Nothink I do or you do or anyone does is good enough for his lordship. See?"

"*I can't say as I do" said the Young Apprentice.*

"You will!" muttered the Oldest Employee darkly. "I bin watching you, me young cockalorum, and if you take my tip you'll go and get another job—where being 'am-'anded and 'alf-witted is an advantage. Go and be an 'eavyweight boxer. Get a job in one of these 'ere Ministries. You won't never do no good here."

"*Why not?" asked the Young Apprentice.*

"Because the Old Man's a Craftsman" said the Oldest Employee. "He ain't never satisfied with nothing and nobody. Not even me. I believe he 'ates 'isself! 'e'll certainly 'ate the very sight of you. 'E's a craftsman."

"*He certainly sounds like it!" said the Young Apprentice.*

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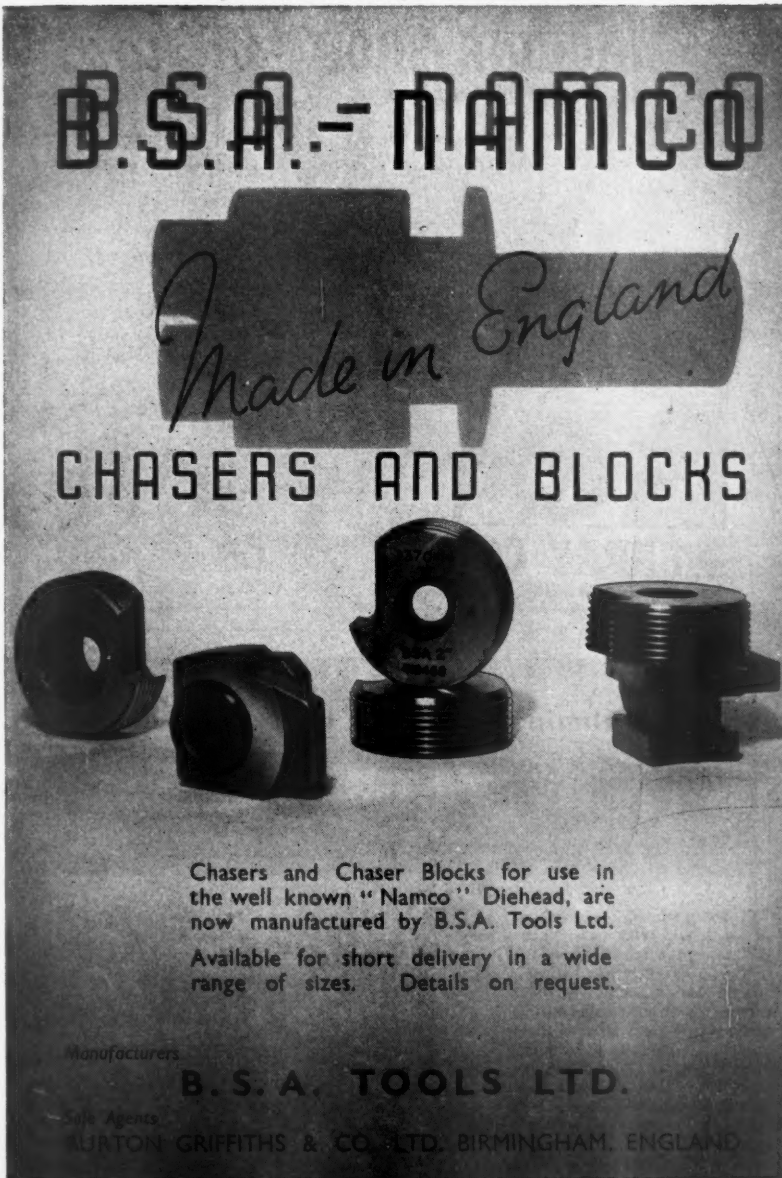
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